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PLATE XX

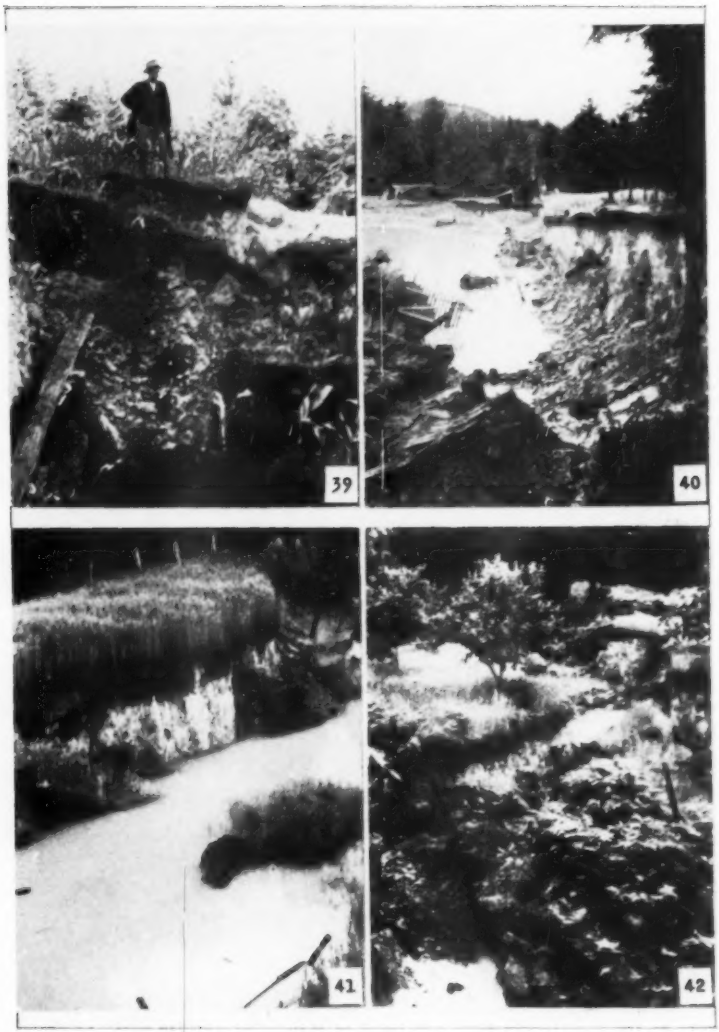

Fig. 39. Down-drops, Read Island (Photo. B.C. Police).
Fig. 40. Down-drops, Read Island (Photo. B.C. Police).
Fig. 41. Down-drops, Read Island (Photo. B.C. Police).
Fig. 42. Wrecked Orchard, Read Island (Photo. B.C. Police).

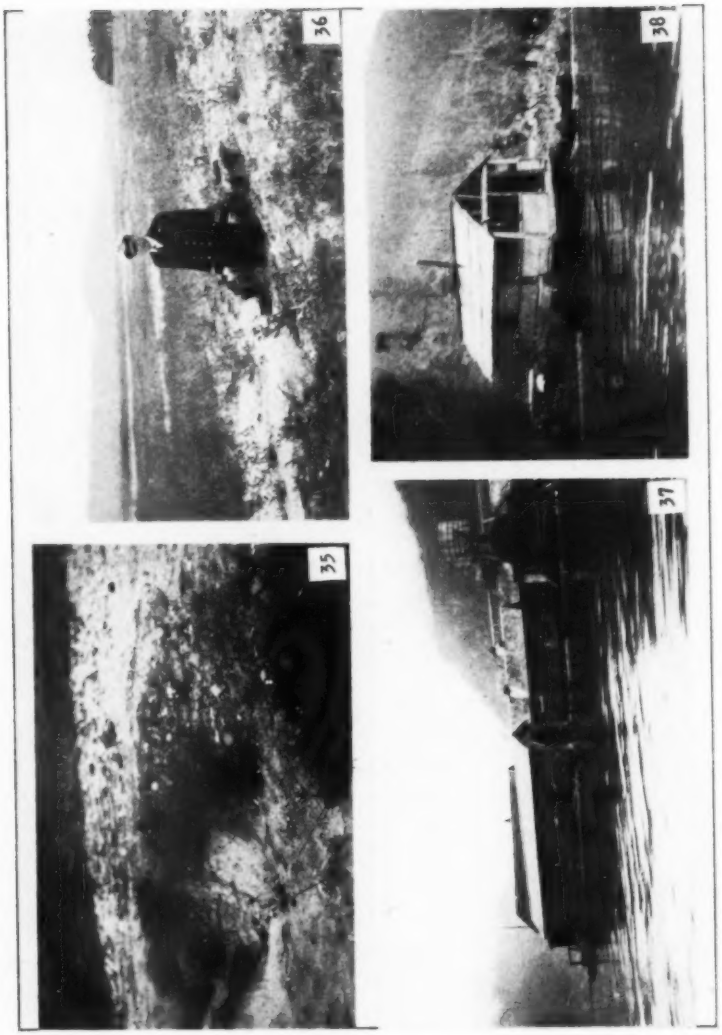

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Fig. 38. Sunken Beach, Comox Lake.

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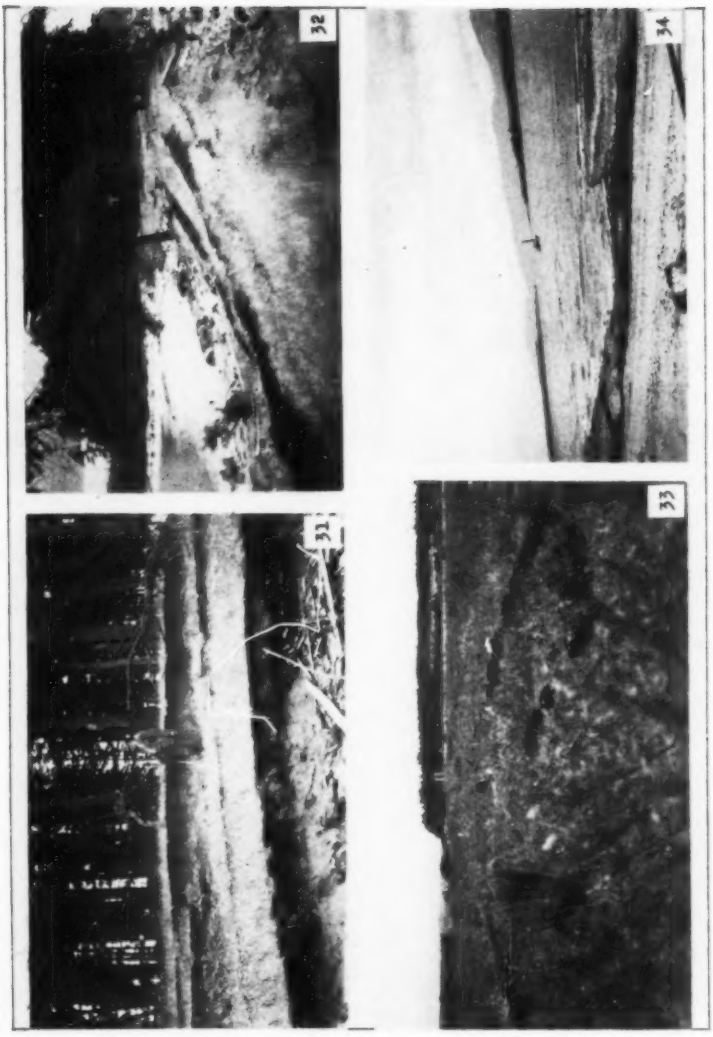

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Fig. 32. Series of Down-drops, Rebecca Spit.
Fig. 33. Sunken Trench, Goose Spit.
Fig. 34. Sunken Beach, Goose Spit.

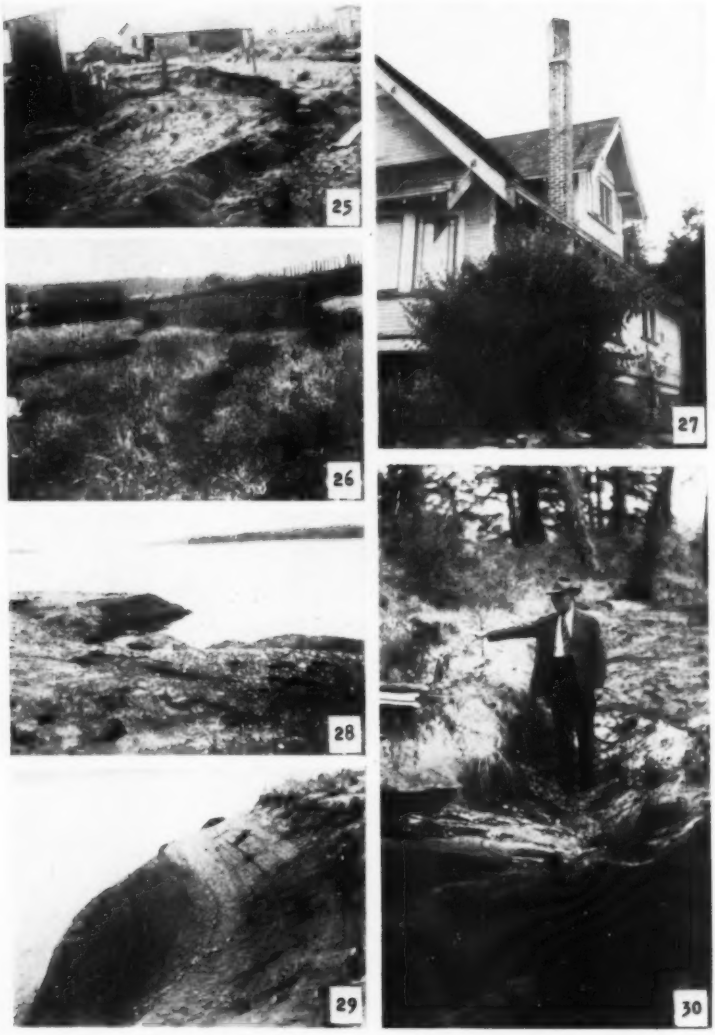
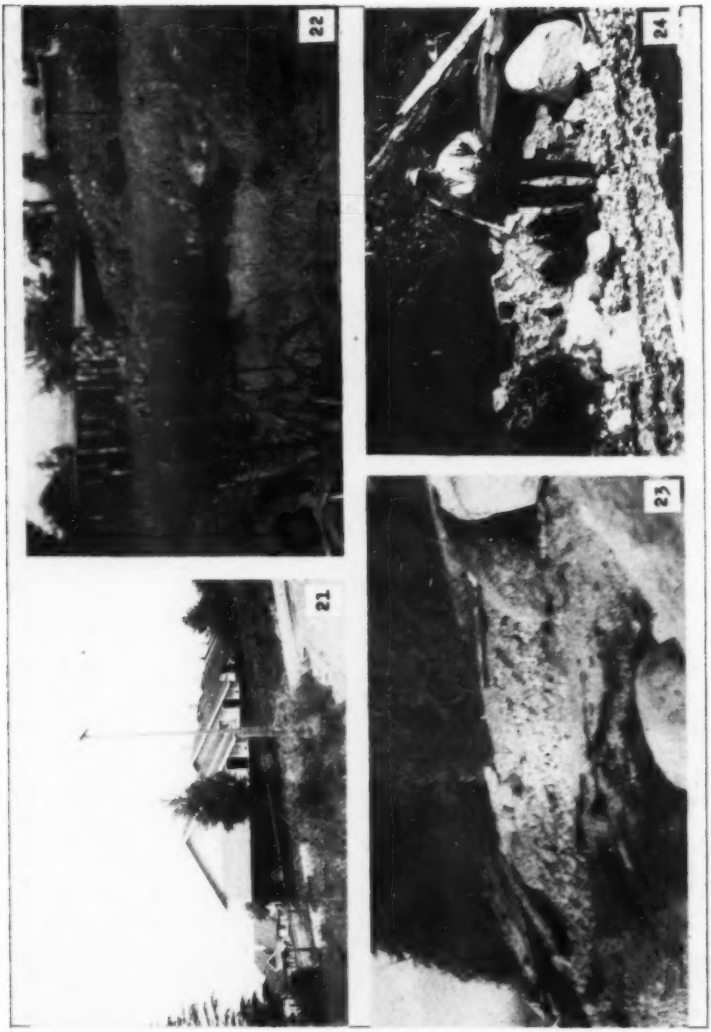


Fig. 25. Sunken Trough, Maple Guard Spit (Photo. B.C. Packers).
Fig. 26. Sunken Trough, Maple Guard Spit (Photo. B.C. Packers).
Fig. 27. Rotated Chimney, Powell River.
Fig. 28. Sunken Beach, Maple Guard Spit (Photo. B.C. Packers).
Fig. 29. Sunken Beach, Maple Guard Spit (Photo. B.C. Packers).
Fig. 30. Sunken Trench and Sand Blow, with Mr. DeGraves, Rebecca Spit.



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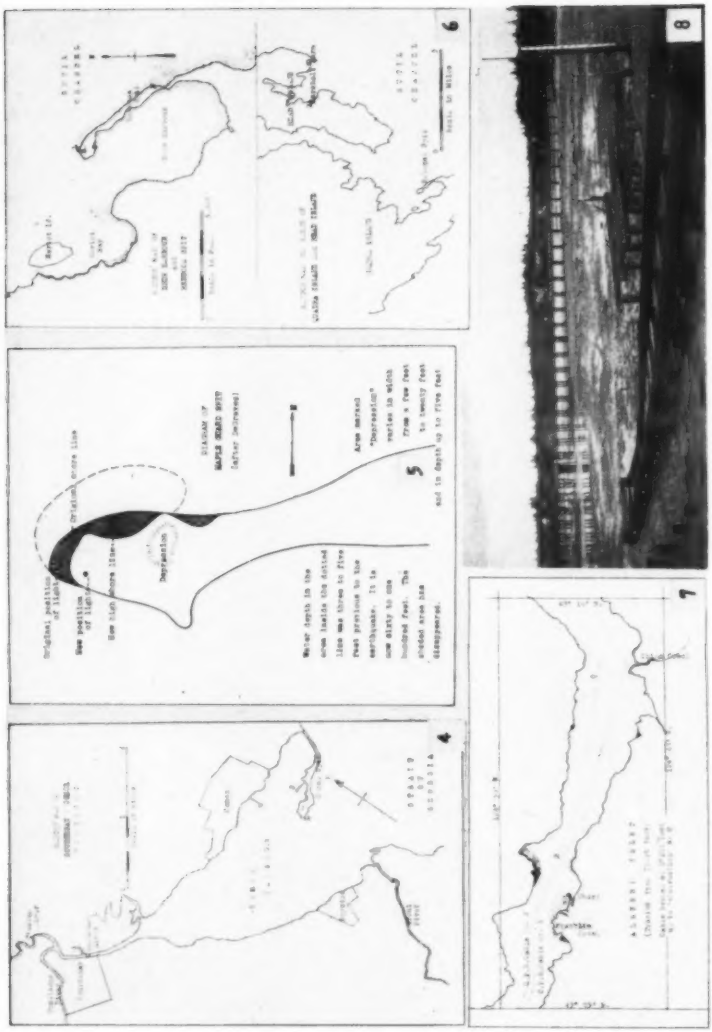

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Fig. 6. Sketch Map, Rebecca Spit and Read Island.
Fig. 7. Sketch Map, Alberni Canal between Franklin Creek and China Creek.
Fig. 8. Damaged Skidway, HMCS. Naden II, Goose Spit.

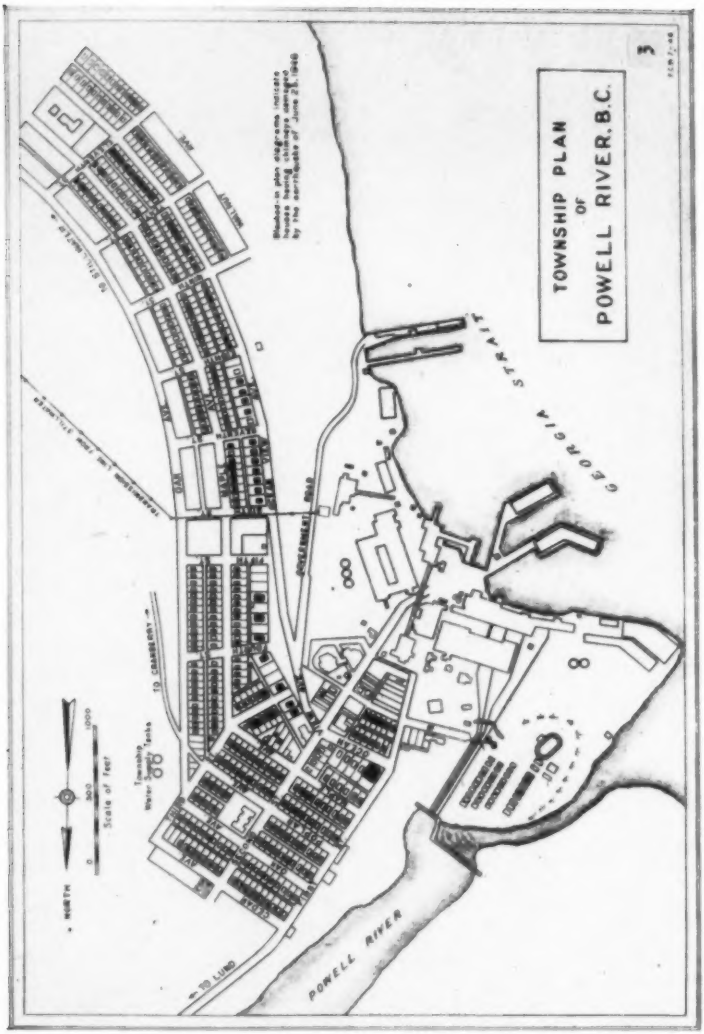


Fig. 3. Townsite Plan, Powell River.

PLATE XI

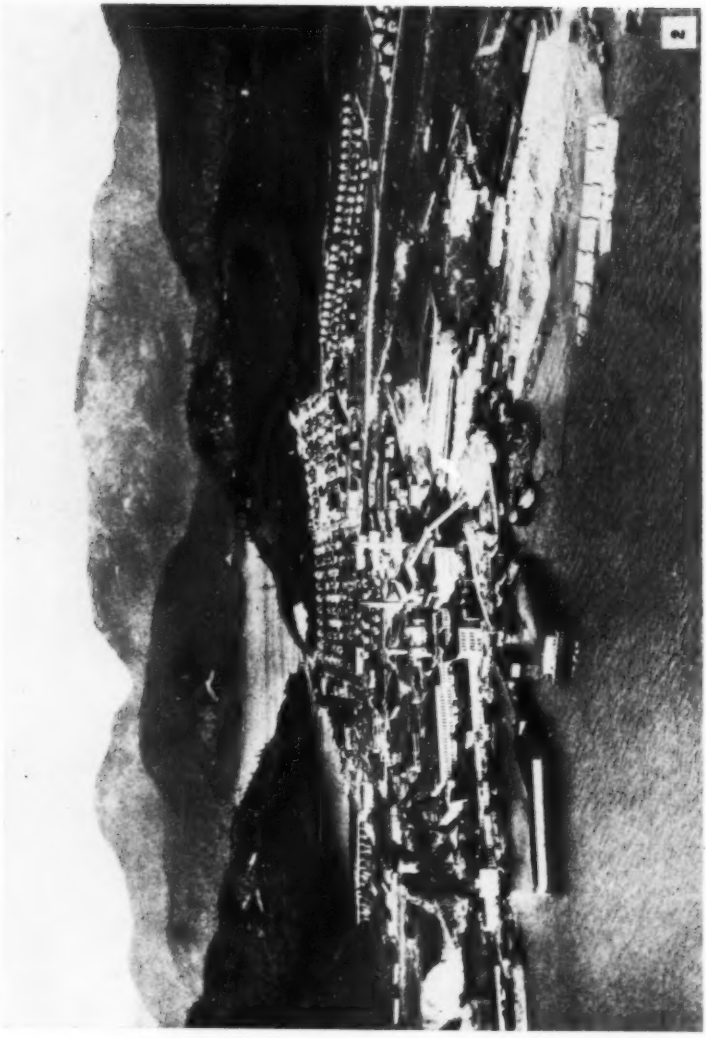
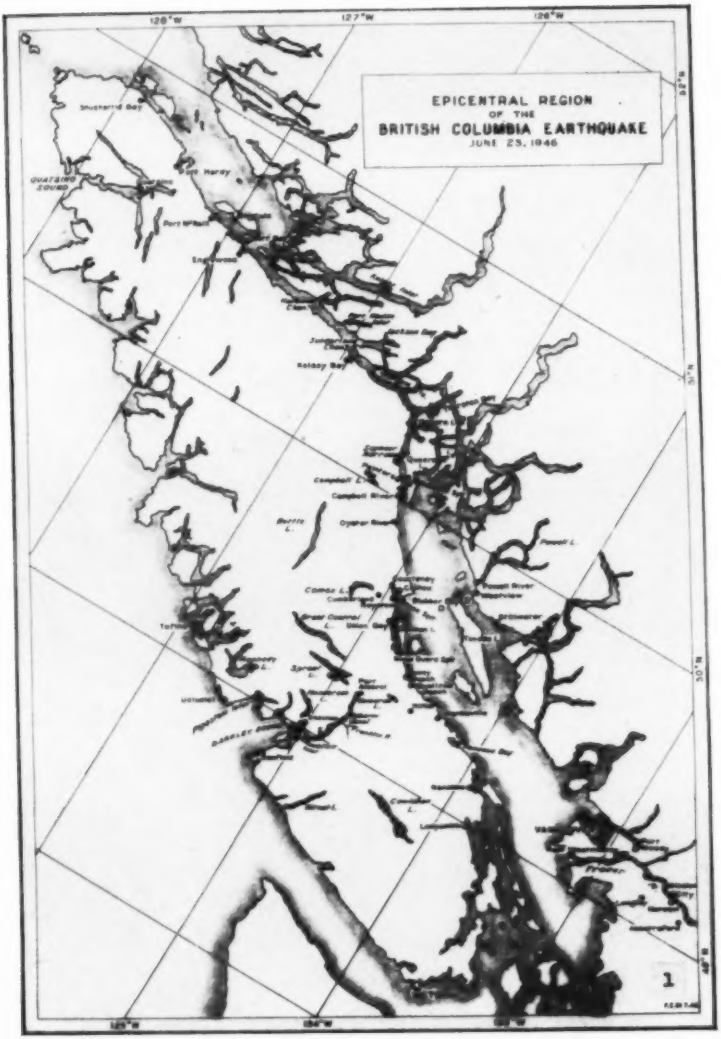


Fig. 2. Airplane View, Powell River.


EPICENTRAL REGION
OF THE
BRITISH COLUMBIA EARTHQUAKE
JUNE 23, 1946
128°W
127°W
126°W
QUATSINO SOUND
Port Hardy
Port McNeill
Alert Bay
Kelsey Bay
Campbell R.
Campbell River
Oyster River
Powell L.
Powell River
Comox L.
Courtenay
Cumberland
Union Bay
Qualicum Beach
Parksville
Nanaimo
Ladysmith
Chemainus
Duncan
Victoria
Sooke
Port Renfrew
Cowichan Lake
Cowichan River
Sproat L.
Great Central L.
Alberni
Port Alberni
Barkley Sound
Ucluelet
Tofino
Clayoquot
Ahousat
Esperanza Inlet
Nootka I.
Kyuquot
Quatsino
Zeballos
Gold River
Muchalat Inlet
Nimpkish River
Woss
Port McNeill
Port Hardy
Alert Bay
Kelsey Bay
Campbell R.

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VOL. XL, No. 8 OCTOBER, 1946 WHOLE No. 357

BRITISH COLUMBIA EARTHQUAKE

June 23, 1946

By ERNEST A. HODGSON

(With Plates X-XX)

AT about a quarter past ten, Pacific Daylight Time, on Sunday morning, June 23, 1946, a severe earthquake occurred at or near the centre of the east coast of Vancouver Island. It was felt as far south as Portland, Ore., and north to about Ocean Falls, while the point farthest east reporting the shock was Kelowna in the Okanagan Valley.

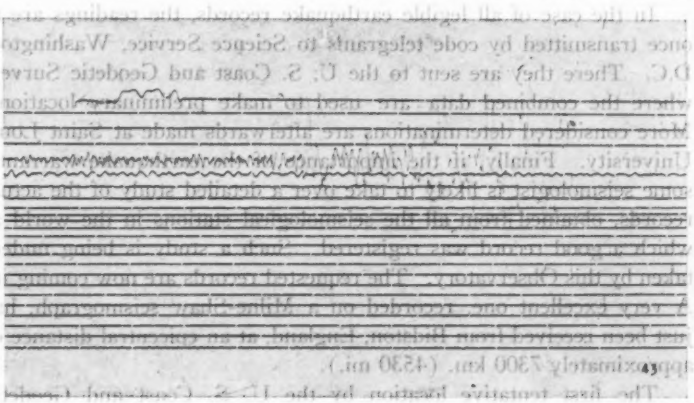

Fig. 43. Section of Milne-Shaw Seismogram, NS-Component, Ottawa.

An excellent record of the earthquake was registered on the seismographs at Ottawa (Fig. 43). It was at once established that the origin time of the shock was about $17^h\ 13^m\ 19^s$ U.T. ($10^h\ 13^m\ 19^s$ a.m., P.D.T.), and that the distance from the epicentre to Ottawa was about 3700 km. (2300 mi.). This would define a circular arc, with its centre at Ottawa and a radius of 3700 km. The arc crosses Vancouver Id. from about Barkley Sound to Campbell River. It is to be noted that these first readings are only approximations, since the records from all stations should be considered together when making a final determination.

To locate the position of the epicentre on this arc requires a triangulation, using stations north or south of the suspected epicentre. It was hoped that Victoria would provide the data needed for this location, but it was found that the shock had proved too severe for the Milne-Shaw seismograph there. The rider connecting the lever system was dislodged, and the record was lost from the moment of the first onset. It was possible, however, even from such a meagre record, to get an approximate value of the epicentral distance. This was found to be about 140 mi., defining a point on the Ottawa arc a little south of Campbell River. This information was available at Ottawa as soon as the Victoria record arrived via air mail.

In the case of all legible earthquake records, the readings are at once transmitted by code telegrams to Science Service, Washington, D.C. There they are sent to the U. S. Coast and Geodetic Survey, where the combined data are used to make preliminary locations. More considered determinations are afterwards made at Saint Louis University. Finally, if the importance of the earthquake warrants, some seismologist is likely to take over a detailed study of the actual records, obtained from all the seismological stations in the world at which a good record was registered. Such a study is being undertaken by this Observatory. The requested records are now coming in. A very excellent one, recorded on a Milne-Shaw seismograph, has just been received from Bidston, England, at an epicentral distance of approximately 7300 km. (4530 mi.).

The first tentative location by the U. S. Coast and Geodetic Survey, sent in response to a telegraphed request from Ottawa, defined a position "in the Strait of Georgia, about twenty miles west

of Vancouver." However, when the data were obtained from other stations and a further study made, the location (still tentative) was sent as "Lat. 49°.9 N., Long. 125°.3 W.", a point about ten miles S.S.W. of Campbell River.

Newspaper reports began to reach the Observatory, telling of serious damage at various points on Vancouver Id. (Comox, Courtenay, Campbell River, Port Alberni, Kildonan, etc.). It was decided that the seismologist should make a field study of the earthquake, going first to Victoria to re-set and calibrate the seismograph, so that it would be in good order for recording any aftershocks which might occur.

Accordingly, he left as soon as plane accommodations could be secured, and arrived at Victoria Monday afternoon, July 1. The seismograph was put in order by Wednesday afternoon, July 3, and, during the same two days, an inspection was made of the earthquake damage in and about Victoria. The field trip then began and continued to July 23. The return trip was made by plane on July 24.

1. *Itinerary and Contacts, Sources of Information*:

During the three weeks spent on the field inspection, the following itinerary was followed:

July 1-3 Arrived Victoria, spent two days rehabilitating the seismograph and also following the routine field procedure: inspecting local damage, searching newspaper files and interviewing local observers.

July 4 At Vancouver.

July 4-5 En route Vancouver to Comox on board C. P. SS. "Princess Mary."

July 5 Union Bay, Courtenay, Comox.

July 6 Courtenay to Campbell River, Quathiaski, Drew Harbour (Rebecca Spit), and return to Courtenay.

July 7 Comox Lake, Bevan, Cumberland, Royston, Qualicum Beach, Deep Bay (Maple Guard Spit).

July 8 Deep Bay and Maple Guard Spit.

July 9 Sunny Beach, Qualicum Beach, Cameron Lake, Alberni, Port Alberni.

July 10 Alberni Canal to Kildonan and return.

July 11 Alberni to Nanaimo via Hilliers, Parksville, Nanoose Bay and then, by bus, to Courtenay.

July 12 Comox and Goose Spit. HMCS. Naden II.

July 12-14 Powell River and Powell Lake.

July 14-15 To Vancouver.
July 16 Up Fraser Valley to Matsqui and return.
July 16-22 Trip by Union SS. "Cardena" from Vancouver to Prince Rupert and return with calls going and/or returning at Telegraph Cove, Englewood, Alert Bay, Sointula, Port Hardy, Shushartie Bay, Namu, Bella Coola, Tallheo, Ocean Falls, Butedale, Prince Rupert, Skeena River Canneries.

From July 5 to July 11, Mr. J. H. DeGraves, Safety and Fire Engineer for British Columbia Packers Ltd., accompanied the writer. This was a most fortunate arrangement, as Mr. DeGraves had made a previous inspection of the company's canneries at Deep Bay and at Kildonan immediately after the earthquake. He was familiar with the roads and the country generally and was able to arrange thorough inspections of properties owned and operated by B.C. Packers, not only on Vancouver Id. and adjacent territory, but on the northern trip as well.

The inspection of Powell River and Powell Lake was most thorough through the interested and whole-hearted co-operation of Mr. D. A. Evans, the Manager of Powell River Company, and his staff.

Captain Hicks of the "Princess Mary" made soundings over Comox Bar on July 5, which the writer was privileged to witness.

Many persons were met from time to time during the field trip from whom valuable information was obtained. Acknowledgment of these contributions will be given in the respective, appropriate parts of this report.

Requests for special official reports were made to: The B. C. Forestry Service, the B. C. Police, the Government Telegraph Service (Department of Public Works, Ottawa), the Canadian Pacific Telegraphs, the Hydrographic Survey (Department of Mines and Resources, Surveys and Engineering Branch, Ottawa), and the Lightkeepers at the various lighthouses on or near Vancouver Id. and the Queen Charlotte Ids. In each case most informative reports were received.

2. *Earthquake Effects at Points Definitely Outside the Epicentral Region*:

The epicentral region definitely runs up the east coast of Vancouver Id., from Deep Bay (opposite the south tip of Denman Id.) to

above Campbell River, including Quadra Id. and Read Id. at the north, and Comox Lake to the west of Courtenay. In addition, there are other locations which may or may not have taken part in the tectonic adjustment. These may be designated as Powell River and its environs and the Alberni Canal together with adjacent waters, especially opposite Franklin Creek on the Canal proper, and at Kildonan, on Uchucklicit Inlet.

Outside these principal and secondary regions of serious activity, the tremors were quite severe over all Vancouver Id., the adjacent small islands, and the coast of the mainland, up to the north-west corner of the Island. Beyond these sections, little damage occurred. The tremors were felt by only a few persons in various localities north of Ocean Falls. At Bella Coola, a new cement foundation was cracked but no other evidences of damage were found. A few houses in Vancouver and New Westminster were reported as suffering plaster cracks but these were either old buildings or were situated on a side hill.

At Matsqui, near Abbotsford in the Fraser valley, a small landslide in a deep, wet "bottom" changed the course of a creek. Landslides were also general all over Vancouver Id. The unusually wet season, the steep slopes so widely found in this province, and the very serious shaking by the earthquake were all responsible for the many slides, some of which would, undoubtedly, have occurred sooner or later without the earthquake. A further discussion of the landslides will be given in Section 3.

The tremors were quite severe in Victoria. About a dozen chimneys were wrecked. These were in two groups, one on Chapman street, the other on Vining street. Some of these chimneys were rotated, as will be mentioned in Section 4. Water mains were broken at two points: Manchester at Sumas and Hillside at Quadra.

Reports from various points on the Olympic peninsula indicate that the shaking was generally quite severe but that little damage was done. Several buildings in Seattle had minor plaster cracks, etc. The tremors were felt by nearly everyone in Portland. The fire chief immediately placed his equipment ready for emergency service but it was not needed.

In addition to newspaper accounts and personal investigations by

the writer at the places visited in his itinerary, much of the information for the conditions outside the zone of maximum disturbance was given by other observers. The region on the west coast of Vancouver Id., from Ucluelet to Tofino, was covered by reports from Mr. Rupert Thomas of Seattle, Mr. Don Mackenzie of Tofino, and several lighthouse stations. Conditions at Quatsino were dealt with in a report by Mr. G. Ildstead, a timber cruiser stationed there at the time of the earthquake. An account of slumps in road embankments south of Kelsey Bay (Fig. 9) was given by the Government Telegraphs (Dept. of Public Works, Ottawa). A general outline of conditions along the north coast of Vancouver Id. and adjacent territory on small islands and on the mainland was furnished by the B. C. Forestry Service (Messrs. L. C. Chamberlin and James Robinson of Thurston Bay, Sonora Id.). Fellow passengers on the "Cardena" told of experiences on the Queen Charlotte Ids. and at Smithers, B.C.

Lack of space precludes a detailed account of the conditions described. In addition to cracked chimneys, broken crockery and glassware, slumped earth fills on roads, crashing of dead trees, etc., the only unusual accounts were those given by the Forest Rangers.

Ranger Robinson reports:

At Jackson Bay (mainland just north of Kelsey Bay) the shore line (west side) slipped away, large rocks along the beach disappeared and the water deepened from 10 to 20 feet. Port Neville deepened from 5 to 25 feet in places at the head of the inlet, according to a local resident who is very reliable. In Havannah Channel (a little farther west on the mainland), it was noted that the water appeared to boil for some considerable time after the earthquake. Knight's Inlet (north of Havannah Channel) reported a number of large rock-slides, some of them seen by myself. All points from Green Point Rapids to the head of Knight's Inlet reported very heavy shaking, but no amount of damage except the odd broken dish and cracked chimney. The most severe shaking was reported by those people residing on mud flats at the head of bays and inlets such as Port Neville, Jackson Bay, etc.

Ranger Chamberlin reports:

Here at Thurston Bay on Sonora Id., the tremors were quite strong. . . . No damage of any extent resulted and no cracks in the earth have been noted. The sea, for some time afterwards seemed to surge slightly. At Deepwater Bay near the north end of the Seymour Narrows on Quadra Id., one of the loggers reports the tremors as quite violent and that the sea, in a matter of seconds, seemed to go from high-water to low-water and back again. No property

damage of any account or cracks in the earth, etc., have been reported. At the head of Bute Inlet another logger reported that there the ground seemed to go in waves like the sea and it was very difficult to stand. A few rockslides were started in this vicinity but no damage or cracks in the earth have been reported. Throughout this district which takes in from the Seymour Narrows to Sunderland Channel, the reports are much the same,—violent tremors but no damage of any account and no . . . cracks in the earth, etc.

3. *Landslides*:

Landslides were general over Vancouver Id. and adjacent territory. As previously stated, many of these would have happened in the near future without the added earthquake cause. Some of them occurred on mountain sides and are quite spectacular, as for example one on Henderson Lake (Fig. 10). Many of the slides did not reach the water of lakes or inlets, being stopped by forest growth above the water line.

Many reports were received of "cliffs 40 feet in height," etc., being formed where once a beach had been. These are a class apart. In such cases, in general, an alluvial fan, resting on a rocky ledge below the water line and sloping up to the nearby hills or mountains, slipped off into deep water. The former beach disappeared and, at the line of cleavage, a "cliff" now marks the broken slope. Such slides were reported from many of the lakes on the Island: Nitnat, Cowichan, Great Central, Sproat, Buttle, etc.

In some cases, the alluvial beach dropped away leaving no cliff, as observed in Cameron Lake, where the former bathing beach is now a steep down-drop in the water close to shore. A wild rose bush, in bloom, was found growing there in about a foot of water, some eighteen inches out from the new water line.

These slumps account for most of the disappearing beaches, but further consideration must be given to the case of Comox Lake (Section 11d) and to Maple Guard Spit (Section 11a), Goose Spit (Section 11g) and Rebecca Spit (Section 11k).

Some slides occurred several days after the earthquake. They were, no doubt, loosened by the tremors. One of these came down onto the highway at Cameron Lake on July 8. Large rocks, some weighing well over a ton, were involved. This potential slide had hung precariously over the road for about two weeks before falling. Fortunately no one was injured.

4. *Cemeteries Visited and Rotation Effects Observed*:

In the case of earthquakes in eastern Canada, the cemeteries afford an excellent guide to the epicentral region. They were not found particularly helpful in this investigation.

Cemeteries at Victoria, Courtenay (2), Comox, Quathiaski (on Quadra Id.), Campbell River, Cumberland, Qualicum Beach and Cranberry (near Powell River) were visited by the writer and others. The one at Nanaimo was inspected by Mr. A. F. Buckham the day of the earthquake. In none, was any certain evidence of earthquake action seen except in the Catholic cemetery at Courtenay. Here, an urn on the top of a very large monument shifted and rotated, but it was so high that it could not be conveniently inspected to determine the sense of the rotation. A small cross in the same cemetery rotated contra-clockwise about twenty degrees.

Most of the gravestones in many of the up-Island cemeteries are of the small pillow type, lying on the ground and generally set in cement. They could not have been affected by an earthquake. In other cemeteries, notably those at Victoria (Ross Bay) and Cumberland, there were many upright stones. No rotations, other than the single case mentioned above, were found. The Ross Bay cemetery was carefully inspected on the day of the earthquake by Mr. C. D. Maunsell, of the staff of the Dominion Astrophysical Observatory. No earthquake effects were found.

With regard to other rotations, the following were observed by the writer: A chimney at Powell River rotated clockwise (Fig. 27). One at Sunny Beach rotated contra-clockwise.

The following rotations (all clockwise) of chimneys in Victoria are authenticated by photographs reproduced in Victoria newspapers: 1355 Vining St. (*Times,* June 24), 1245 Chapman St. (*Times,* June 24), 1253 Chapman St. (*Colonist,* June 25).

A photograph, taken by a local resident in Port Alberni and purchased by the writer, shows that the chimney affected had turned clockwise (Fig. 19).

Reports of other rotations were given as follows: A chimney at Duncan was reported by Mr. Buckham as having turned clockwise. A large statue, housed in a niche over the door of Saint Joseph's Hospital, Comox, was reported by Mr. Meier, who re-set it, as having turned contra-clockwise.

In the case of the Saint Lawrence Earthquake of 1925,* many chimneys and gravestones turned. In general, those on the north shore turned clockwise; those on the south shore turned contra-clockwise. The epicentre is believed to lie between these.

In the case of the Cornwall-Massena Earthquake of 1944,† many chimneys and gravestones were turned. In general, those on the north shore turned contra-clockwise, those on the south shore turned clockwise.

In the British Columbia Earthquake, not many rotations were observed; all are reported above, a total of ten. These are distributed in such a manner that, if a line be drawn, associated with maximum disturbance (up the Alberni Canal to Alberni, across the height of land to Qualicum Beach, thence through Deep Bay and up the coast to Campbell River, Quadra Id., and Read Id.), then all situated south and east of that line turned clockwise and all north and west turned contra-clockwise.

There were some other rotations observed but the evidence as to the sense of rotation is conflicting. As observed by the writer and Mr. DeGraves, one of the cases was clearly contra-clockwise, but it is included in a group reported as having all turned clockwise. It is believed that this report was given by an observer regarding the turned part of the chimneys *from below*. "Clockwise" and contra-clockwise," as used in this report, are applied as looking *from above*.

No deductions may be drawn from the rotation data; they are much too few. The information is listed in this report merely to indicate that efforts were made to secure such data, and to show that the distribution of the few cases found does seem to have some relationship to the line of greatest disturbance.

5. *Tremors Observed on Board Ship*:

The Union Steamship "Cardena" was out in the channel after leaving Shushartie Bay en route to Port Hardy (see point A in Fig. 1), at the time of the earthquake. The man at the wheel reported to

*See this JOURNAL vol. 19, p. 169, 1925.
†*Idem*, vol. 39, p. 5, 1945.

Capt. A. C. MacLennan that the compass was trembling. This he verified, but they did not know, at the time, that an earthquake was the cause.

The C. P. Steamship "Princess Mary" was north-east of Texada Id. (see point C in Fig. 1). Capt. Hicks reports that the tremors were such that the ship seemed to have run over a sand bar. The engines were stopped and the tail shaft examined. Finding no trouble, they resumed their course but did not know there had been an earthquake until they reached Blubber Bay.

The Union Steamship "Ventura" was south-west of Texada Id. (see point D in Fig 1). There was general consternation on this ship. They thought at first she had struck a rock (not a sand bank). Then they realized they were experiencing an earthquake. This was reported by Capt. MacLennan of the "Cardena." It was not found possible to meet Capt. Suffield of the "Ventura."

The motor launch "Uchuck" (Fig. 20) was just off the port of Franklin River in the Alberni Canal. Capt. Young and his engineer, Mr. McCandless, thought at first that the tail shaft had broken. They report that "no wave of any kind appeared until we were down the canal several miles, when a series of gentle rollers crossed the channel from west to east, seeming to be generated at the mouth of Nahmint River," which enters from the west shore below Franklin River (which is on the east shore). These rollers were neither high nor narrow. They were long, gently-sinusoidal swells, very broad and flat. This evidence seems to be at variance with that given by a local observer to the C.P.R. Telegraph officials, investigating the broken telegraph cable. See Section 6 for further discussion of this point.

The barque "Pamir" was, according to a copy of the ship's log, authorized by the Captain and furnished by Mr. A. F. Jenkins, at Lat. 37° 30′ N., Long. 144° 22′ W., i.e., 1,021 miles south-west of Cape Flattery. They had been becalmed for about four days and were in an excellent position to note any tremors. None were felt, and they did not know anything about the earthquake until they received the radio news.

6. *Damage to Submarine Telegraph Cables*:

The telegraph cable from Blubber Bay to Powell River parted at the time of the earthquake. Information received was to the effect that the break occurred at a splice which had previously given trouble, that the cable was repaired in a few days, and that it was again in operation (July 12).

Serious damage was caused to the C.P.R. Telegraph cable in the Alberni Canal near Franklin River. The report by Mr. L. A. Raymond, Superintendent of Communications, is given as follows:

It was not the trans-Pacific cable that was damaged; it was the shorter cable approximately thirty miles in length connecting the cable station at Bamfield with our overland telegraph wires at Port Alberni. We have two cables laid along the inlet and they were both damaged that day.

A local person at Franklin River who witnessed the earthquake said that a ridge of water, twenty or thirty feet high, rose in the middle of the inlet, extending in a north and south direction. This rise in the water level caused a small tidal wave on each side of the inlet.

When we tried to pull up our No. 2 Cable to repair it, we found that it was held solidly on the bottom by some obstruction at a point approximately opposite China Creek. We were unable to move the cable by having a tug pull on it in all directions, or by winching it. We were unable to find either cable between China Creek and Franklin River by grappling. (See Fig. 7). This may have been due to the difficulties entailed in grappling for a cable in this depth of water. It has been conjectured that the bottom of the inlet may have developed a fissure and pinched the cables solidly in that section.

At a point about 800 feet north of Franklin River wharf there was a clean break in both cables. We were only able to find the Bamfield ends of these breaks. We were unable to locate any portion of the cables between these breaks and the obstruction opposite China Creek.

In the area of the obstruction, the Admiralty charts showed a depth of 300 feet. Our soundings showed a depth of 440 feet. In the area between China Creek and Franklin River, soundings were taken at several places during the search for the cables and we found the depth was 50 to 200 feet greater than shown by the charts. At one place on the east bank of the inlet, the tugboat skipper measured a depth of 100 feet where previously the rocks had been exposed at low tide.

Our electrical measurements showed another fault in the No. 1 Cable, at a point 8.3 miles from the Bamfield end. Due to the extreme depth of the water at this point, we have not yet attempted to grapple for the cable in this area.

With regard to the ridge of water "twenty or thirty feet high," as reported by the local observer to the C.P.R. Telegraph Co., and

a statement by Capt. Young that "the sea was like glass and no waves were observed until opposite Nahmint River, when long low swells were observed sweeping across the channel," i.e., from west to east, it may be noted that, at the instant of the earthquake and for some little time afterwards, Capt. Young and his crew were under the impression that some mechanical trouble had developed on their boat. Moreover, if the ridge were very wide and not in the nature of a wave, an observer on the boat would be in the poorest position to see it, while one on shore would have the best opportunity. It is quite likely that both stories are essentially correct. Certainly, the sea was smooth; there was no wind, and there were no waves as such. A long, smooth, wide swell would hardly be noticed on board the boat. It is likely too that the estimate of height is somewhat too great on the part of the land-placed observer.

Of particular interest is the complete agreement of all measurements that there was, if anything, a deepening of the channel as well as the shore line. This is a matter of some importance. If the cable was broken because a large mass of alluvium slipped off the submerged shelf at the shore line, and if no drop occurred in the channel, then the shore depths should be greater (as they certainly are) but the channel should be *less* deep.

If the Alberni Inlet is part of the epicentre proper and a drop occurred in the bottom of the channel, then it would be most important if this could be proved. Unfortunately, the earlier measures of depth, as given on the chart, are not echo-sounding profiles, but old Admiralty measures, not too precise as to depth, and even less precise as to position. In view of the scientific value of the facts, could they be established, a request is being made to the Hydrographic Survey to run echo-sounding profiles in the waters designated above and also throughout the main epicentral region described in Section 11. The Geodetic Survey has also been asked to re-run their line of precise levelling up the east coast of Vancouver Id. from Parksville to Campbell River.

7. Effects in Coal Mines:

No attempt was made to visit the coal mines in the Comox area, since reports received from residents agreed with accounts in the newspapers to the effect that no damage had occurred in the workings.

In the case of most earthquakes, miners underground seldom notice the tremors. This is natural. A miner's first care is to render all workings safe and capable of withstanding the concussion from blasts in adjacent workings. If loose is not to come down with a blast in a stope a few hundred feet distant, it will not fall because of an earthquake which does not originate in or very close to the mine.

Moreover, since mine locomotives and trucks are always being moved about on the same or adjacent levels during shift hours, a miner is not likely to notice the rumblings caused by an earthquake. At all events experience shows that they seldom do.

It may confidently be stated that none of the changes in land level or in water depths, occurring at the time of the earthquake, had any connection with underground excavations made by mining.

8. *Reports from Lightkeepers*:

In response to an official request for reports on the earthquake, from lighthouses around Vancouver Id., a summary for twenty-six stations has been received through Mr. W. L. Stamford, Department of Transport, Victoria. These accounts give an excellent review of conditions all around the coast.

In every case, the earthquake was felt; but, at most lighthouses the effects were not particularly startling. Windows were cracked, some oil or mercury (used to float the rotating lenses) was spilled, or dishes fell. Nearly every lightkeeper reports that no changes were observed on the sea. The single exception to this was at Sisters Rock (south of the centre of Texada Id. and east of the southern tip of Denman Id.). The report reads: "One tidal wave came at 10.22 a.m., seven minutes after the earthquake. The wave was seven to eight feet high. A second wave 100 feet from the first was four to five feet high. The speed was ten knots." This would seem to indicate roughly that the wave was generated at about Deep Bay or Union Bay.

A small amount of mercury was lost from the lens float at Pulteney Point lightstation (on Malcolm Id. off Port McNeill) and at Lennard Id. (off Tofino). At Gallows Point lighthouse (on Protection Id. off Nanaimo) "five or six pounds of mercury was shaken out" and at Estevan Point (on the west coast of Vancouver Id.

at about Lat. 49° 25′ N.) "900 to 1000 lbs. (of mercury) spilled over."

The shaking at Estevan Point seems to have been particularly severe. "Some of the prisms were shaken right out of the lenses and some were ground to a fine powder, like flour. Two large panes on the N.E. side of the lantern fell out in very small pieces."

Other lighthouses on the west coast do not indicate any severe shock such as seems to have been experienced at Estevan Point. It is to be noted that this lighthouse is the one on the west coast nearest to the tentative location S.S.W. of Campbell River.

Lightkeepers stationed near Victoria and near Vancouver respectively, report having felt the tremors but state that they observed no other effects of the earthquake.

From Cape Mudge (southern tip of Quadra Id.) it is reported that "the colour of the tide in the rip changed to a green-blue within half an hour of the quake. . . . The fish stopped biting." It was the general experience of fishermen (supported by the records at the canneries) that the fish stopped biting throughout the epicentral region. Normal catches were not obtained for nearly two weeks. This may have been due to the fact that the sea became muddy and the trolls could not be seen.

Mr. Stamford states that reports from some other lightkeepers are expected and will be forwarded when received.

9. *Earthquake Effects at Points Possibly Within the Epicentral Region*:

The section which may be within the epicentral region but which, on the other hand, may simply have suffered "neighbourhood damage" due to proximity to that region may be designated as the Alberni Canal from Barkley Sound to Alberni and the mainland in the vicinity of Powell River. Arguments for and against considering these as truly epicentral will be given in each case. They may be discussed in order from west to east.

(a) *Kildonan*:

At the B.C. Packers' plant at Kildonan on Uchucklicit Inlet, damage officially estimated as from $25,000 to $30,000 was caused by the earthquake. It is believed that this was due simply to the

slipping off into deep water of part of the alluvial fan on which the plant is built. A photograph furnished by Mr. DeGraves is given as Fig. 11. See also Fig. 12. The front (seaward) end of the plant rests on piles which were driven into the outer edge of an alluvial fan. When the earthquake occurred, the front part of the fan slipped off into deep water. The centre of the wharf slumped down as shown in the photograph.

At the time, ice was being crushed for shipping fresh salmon. An ice plant at Kildonan supplies this refrigerant in large quantities. The crusher was operating on the wharf. When the slump occurred, the machine fell into the water, carrying the operator. He was unable to swim and, with a broken shoulder, was in some danger. He was rescued and sent to Alberni hospital.

At the back of the plant, a steep cliff rises for perhaps a hundred feet. The power plant penstock resting on trestles on this slope was not injured. Eleven chimneys were damaged, an oil tank sprang a leak and another slopped over. Goods were thrown from shelves in the store and in the cafe.

The major part of the damage occurred in the cannery. This was not in operation at the time, but the machinery was broken or thrown out of alignment. Most of the expense involved was concerned with putting this equipment into operation again. The damage here was reported in detail to his Company by Mr. DeGraves, who furnished a copy, which has been largely drawn upon in this report.

It seems safe to assume that the damage at Kildonan was the result of the slip-off of the alluvial fan. On the other hand, serious landslides occurred in this vicinity which indicate that the shock was intrinsically severe (Fig. 10). It would be most valuable could changes in depth be determined in Barkley Sound, Alberni Canal and Uchucklicit Inlet.

(b) *Franklin River*:

The effects at this point on the Alberni Canal have been discussed in connection with the report on the rupture of the telegraph cables (Section 6). The position of the Franklin River wharf is shown on the sketch map (Fig. 7). It is to be noted that it stands on the edge of an extensive alluvial fan at the mouth of the Franklin Creek.

There was no damage of any consequence to this structure according to Capt. Young. The "Uchuck" was just off this point at the time of the earthquake and has since regularly made Franklin River wharf a port of call. Whether or not the epicentre includes this section of the Alberni Canal, it is difficult to say.

(c) *Port Alberni*:

At Port Alberni there were quite a number of chimneys damaged, including one on the hospital, the latter resulting in some anxious efforts to rebuild it and restore full hospital services. However, most of the chimneys affected were in those sections of the town built on low-lying land. Those houses built on rock were little damaged. Losses incurred by stores due to the falling of goods from shelves varied greatly according to the type of terrain involved. The liquor store reported "no damage to the Scotch and only a few bottles of gin, rye and beer." This store is built on a rocky ledge.

The tower of the post office was damaged by the heavy clockwork shifting in its anchorage. The front of the building was barricaded and business continued as usual, entrance being gained through a rear door. A rotated chimney in Port Alberni is shown in Fig. 19.

The brickwork of a boiler was thrown down in the lumber mill of Bloedel, Stewart and Welch, breaking the pipe connections. It was not in operation at the time. The high smoke stack was not injured. This is rather remarkable since the mill is built on an alluvial flat at the head of Alberni Canal. The mill was shut down for some days after the earthquake while repairs were being made.

(d) *Alberni*:

In "Old Alberni" many chimneys were thrown down, but mostly in the case of older buildings or those on deep ground. Mr. Stevenson, the Ranger, states that his house, built on rock, suffered no damage. Nothing was thrown down in the house except one plate.

The "Motion Block" in this town was damaged as shown in Fig. 17. This received a good deal of newspaper publicity but was not very important as earthquake evidence. A flat roof on a brick veneer structure, none too well built and on deep ground, shifted back and forth, knocking several of the top courses of brick into the street. No one was injured.

As one drives east from Alberni toward Parksville, the houses show damaged chimneys for a few miles, as far as but not including Hilliers. The telephone wires, especially in Cathedral Grove section, were broken by falling trees.

To sum up: this region from Barkley South to Cameron Lake presents some evidence in favour of its having been part of the epicentre. If changes in depth in the centre of the Canal could be proved, it would have to be so considered. On the other hand, all the observed phenomena would be explained as "neighbourhood" damage if no such changes had occurred. Although Powell River is included in the section of suspect epicentral nature, it presents so many features of special interest that it is discussed in the next section.

10. *Powell River*:

The inspection of this town was particularly thorough through the valued co-operation of Mr. Evans and his staff. The town is built on a bank sloping rather steeply near the water's edge and then more gently back toward the mountains. Powell Lake, about a mile inland, discharges into the Strait of Georgia through Powell River, which is dammed and provides power for Powell River Mill. A photograph of the mill and townsite is shown in Fig. 2, and a plan of the latter, furnished by Mr. Macfarlane, Townsite Superintendent, is reproduced as Fig. 3.

The town is owned by the company and its maintenance is under the supervision of Mr. Macfarlane. He has indicated all the houses which suffered damaged chimneys. It is to be noted that these occur in groups. Further, no house in the section bounded by First and Third Streets and by Cedar and Maple Avenues was so affected. These are built on rock. Where the damage is not general for all houses in a block, the chimneys overthrown were those which had not been repaired for some years. In general, new or recently repaired chimneys stood the shock very well except in those blocks where all went down. It is difficult to say why whole blocks of houses should be affected while others with taller chimneys and nearer the steep slope to the Strait suffered no damage.

In view of the fact that sporadic damage is often found in earth-

quake epicentres and is usually difficult to report with certainty, the official townsite plan of Fig. 3 is here reproduced. All except the one section above mentioned is built on sand and gravel and the damage is completely reported. Why the distribution should be as shown one cannot say with any certainty. The row of houses facing on Ocean View Avenue, between Tenth and Eleventh Streets, is shown in a photograph (Fig. 21) taken from the north end of the school in the next block south. These chimneys are not nearly as high as is the one in the next block west, shown in the same photograph. Moreover, this tall chimney, together with others in its block, is nearer the steep slope shown in Fig. 2.

The mill was not in operation at the time of the earthquake, a Sunday morning. It was not damaged except for a few broken pipes. In the town there was a good deal of damage in the houses, where dishes, etc., were thrown down. One plate glass window was cracked; but others, in equally vulnerable houses, suffered no damage.

Chimneys were damaged in Cranberry and Westview. One at Wildwood, just north of Powell River, near Powell Lake on the road to Lund, was turned 45° clockwise (Fig. 27). No damage was found in the cemetery at Cranberry, though there are quite a number of upright gravestones in the grounds.

The type of damage above reported would appear to place Powell River definitely outside the immediate epicentral region, but two other cases must be considered. Reference has already been made to the breaking of the telegraph cable between Texada Id. and Powell River. However, this parted at a splice which is reported to have given previous trouble. The second case is not so easily disposed of.

About a quarter of a mile south of Westview, the steep bank bordering the Strait of Georgia becomes a cliff or bank of gravel about thirty feet high with its foot about high-water mark. The road skirts the top of this bank. At the time of the earthquake a section of the road slumped away but slipped only a few feet down the bank as indicated by the bushes and underbrush. At high-water mark on the beach, a great welt was formed, presumably accompanied by an upthrown sheet of water. This welt is 180 feet long, about 3 feet wide and was originally 5 feet high. The clay which came out of it is cracked deeply along the centre of the welt, and is of the

consistency of rather poorly-made cement. A piece of it, about the size of a baseball, carried for two weeks in a brief case and since lying exposed on a desk, shows no signs of disintegration.

This welt was thrown up with sufficient force to break a fallen tree held in the bank by its roots and lying across the welt. The tree is about 18 inches in diameter but is badly weathered. The nature of the welt is shown in Figs. 23, 24. The tree which was broken is shown at the left-hand end of Fig. 23. In addition to the welt on the beach, but seemingly caused by a break half-way up the bank, a sort of crevasse is formed in the slope. It has opened up much as a cylindrical dunnage-bag opening appears when the zipper along its side has been pulled and the long opening gaps. This crevasse is about ten feet long, two to four feet wide and about five feet deep. It was not possible to get a good photograph of it. There seems to be no immediate connection between the welt, the crevasse and the slump on the roadway. All were caused by the earthquake, but the first was due to an up-thrust of water, and the other two to slump of a side hill.

Above the welt, beyond the road at the crest of the bank, is a lawn and garden owned by Mr. Gus. Courte. On the lawn are three fish ponds. The one shown in Fig. 22 has no retaining wall, the water being a foot or more below the grass bank. This pond is stocked with edible-sized trout. At the time of the earthquake, Mr. Courte was feeding the trout. When the shock came, he and the man with him threw themselves on the grass at the side of the pond. He states that the water in the pond was thrown into a swishing surge which dashed water over them and left barely enough in the pond to cover the fish. The writer was impressed with Mr. Courte's observing and reporting capacity in connection with other matters which he was himself able to check. There is no reason to doubt that this is also true. That the chimney on the adjacent house was not damaged may be laid to the freakish results seen elsewhere in the case of this earthquake (and others).

So far as could be found, the welt on the beach at Westview is the only case where the ground, surface or submarine, was *raised* by the earthquake. Newspaper stories of "cliffs thirty feet high," etc., refer to the steep face left when an alluvial fan breaks off and slips

into deep water; or, in the case of Read Id., to which reference will be made in detail later, to the steep sides left bordering undisturbed level ground at the edge of a sink.

On the whole, it would seem reasonable, in spite of the welt on the beach, to consider Powell River as lying outside the immediate earthquake zone. At Stillwater, south of Westview, is a large power plant supplying Powell River Mill. No damage resulted there. Mr. Templeton, the engineer who inspected the plant after the earthquake, reported that there was no damage in the plant, but that the penstock began to deliver muddy water after the shock.

This penstock runs from the Gordon Pasha Lakes to Stillwater. It is over two miles long. The upper section is nearly horizontal and is cut through competent granite rock, except for the first 300 feet, which is in gravel. The tube is lined with reinforced concrete. It was de-watered and inspected carefully, especially at the point where it passes from gravel to rock and at the joint where the second half dips down to the power house. No damage was found. The surge tank, about 300 feet high, was also undamaged. If Powell River were in the epicentral zone, one would expect more evidence of it in the mill there and in the power plant at Stillwater, only a little over ten miles distant in an air line.

11. *The Epicentral Region*:

The section of the east coast of Vancouver Id., which certainly may be described as the epicentral region, extends from Deep Bay, opposite the south end of Denman Id., up to Campbell River, Quadra Id., and Read Id. Evidence that Comox Lake is also in that region seems conclusive. It is possible that a second disturbed fault extends south-westward from Comox, through Comox Lake, down the connecting valley to Alberni, and thence down the Alberni Canal to Barkley Sound. In any event, Comox Lake must be included as part of the epicentre. The evidence throughout the epicentral zone will be discussed with reference to the places affected, beginning at the southern end.

(a) *Deep Bay and Maple Guard Spit*:

Deep Bay is protected by Maple Guard Spit, which extends westward on the north side of the Bay between that body of water and

Baynes Sound,—the channel between Denman Id. and Vancouver Id. A diagram of Maple Guard Spit is reproduced (after DeGraves) as Fig. 5. On the spit is built the B.C. Packers' cannery, together with the houses occupied by those employed there. The effects of the earthquake are shown in pictures supplied by Mr. DeGraves and presented as Figs. 13, 25, 26, 28, 29.

The damage at this point was inspected by Mr. DeGraves the day after the earthquake, at which time the above pictures were taken. It was again inspected on July 8. Some of the details below were still in evidence, others had disappeared by the action of rain and tide, while others were greater than when seen two weeks before.

On the Sunday morning of the earthquake, a fisherman, Capt. Daniel Fiddler, was engaged in loading ballast into his motor boat anchored off the tip of Maple Guard Spit. He was using a dinghy without oars. Being close to shore, he simply pushed the dinghy back and forth from boat to shore as needed. When the earthquake occurred, the west end and north side of the spit disappeared. The extent of the change is shown in Figs. 5, 29. In the wave caused by the subsidence, the dinghy capsized. Fiddler was thrown into the water but his companion managed to get into the motor boat. Fiddler swam about for a few strokes and then disappeared. His body was not recovered until July 10, being found about a mile and a quarter distant from the point where his boat capsized.

As reported by Mr. DeGraves, the spit was markedly changed by the earthquake. As of June 24, he writes: "About twenty feet of the spit at the west end has disappeared. It was necessary to remove the navigation light at the end of the spit, back toward the east about eighty feet in order to save the light from going into the water" (see Fig. 29). By July 8, much more of the end of the spit had disappeared, leaving it as shown in Fig. 5.

Where the water at the north side of the spit was only two to five feet deep at high tide on a shelving beach, it is now a hundred feet deep. A deep bay encroaches on this side as shown in Fig. 5. Indentations in the beach (Fig. 28) indicate the extensions under water of down-dropped trenches on the spit (Figs. 25, 26). In places these trenches on the land reach a depth of five feet. It is to be noted that the trenches and depressions are not caused by the slump to the

water. The largest one crosses the spit in a north-south direction as an extension of the "depression" shown in Fig. 5.

In places on the spit are craters several feet in diameter, some in the trenches, some on ground otherwise not marked by cracks. They are referred to as "sand blows." At the time of the earthquake, geysers of water, forced up under pressure, carried sand, mud and sea shells to heights estimated by various observers as about thirty feet. They are reported all along the coast, on the land and in the water, from Deep Bay to points above Campbell River. On June 27, Mr. DeGraves was unable to reach bottom with a twelve-foot pole in some of the larger ones on Maple Guard Spit. By July 8, the elevated craters on this spit had become saucer-like depressions, some three feet in diameter and a foot or more deep.

A net loft, built on the south side of the spit, rests on piles which stand in water at high tide and are almost all uncovered at low tide. Around each of these piles there appeared sand blows. Some of the piles were pushed up, some were sucked down (as indicated by barnacles on the piles), with the result that the net loft was badly distorted as shown in Fig. 13. The distortion there shown was all caused by the earthquake.

The houses on the outer end of the spit are arranged in two rows with a road between, running up the long east-west axis. Along this road, buried a foot or two below the surface, is a wood-stave pipe for supplying fresh water to the houses. An iron service pipe runs into this stave pipe opposite each house. The service was all disrupted and investigation showed that the service pipes had pulled out about eighteen inches from each side of the stave pipe, indicating a slump in both directions across the spit,—toward the bay and toward the strait. Compare this with the later description of Rebecca Spit. (Section 11k.)

Some of the houses toward the outer end of the spit were in close proximity to the sinking trenches. These trenches continued to sink slowly for several days. The houses were vacated at Mr. DeGraves' direction, but were occupied after the inspection on July 8, all subsidence having been over for some time.

Damage to the cannery property, houses, etc., is estimated officially by Mr. DeGraves as between $2,000 and $2,500. Eleven chimneys were damaged, some thrown down and others cracked near

the roof line. Considering the shake-up at the end of the spit, it is remarkable that any chimneys stood.

Some of the fissures bordering the trenches were very deep when first observed and varied in width from mere cracks to eighteen inches. By July 8, they had all filled to within a short distance of the surface, but their position and width were still plainly visible. As the season was very wet and the soil is sand, it is remarkable that they remained visible for over two weeks.

It is to be noted that there is good evidence here of a true tectonic drop in the rocky foundation of the spit. There would seem to be no other explanation of a down-dropped trench with escarpments facing inward on both sides and running across a level section of the spit as shown clearly, for example, in Fig. 26. Again, be it noted that all changes reported are down and all water depths changed have become greater.

(b) *Union Bay*:

This village, between Deep Bay and Comox, is the shipping port for Comox coal, mined mostly in the vicinity of Cumberland. A long, high jetty or wharf carries loaded coal cars out to the side of coal-carrying ships. At the time of the earthquake, a large vessel was close-moored to this jetty. The earthquake caused so much relative motion between the ship and the jetty that the latter would certainly have been wrecked had the tremors continued much longer.

Hardly a chimney was seen undamaged in Union Bay. It is confidently believed that all must have required repairs. Here, as elsewhere in this district, the houses are of wood and not susceptible to damage except as to chimneys, windows, crockery, etc. Of all the villages and towns visited, the chimney damage in Union Bay easily rates the highest percentage. No other earthquake effects were observed or reported.

(c) *Royston and Cumberland*:

It was reported that: "180 chimneys were knocked down in Cumberland." Nevertheless, when Mr. DeGraves and the writer visited the town on July 7, they drove through it, street by street, making a careful observation of the chimneys. Counting obviously new chimneys on old houses as having been damaged and adding those still obviously needing repair, not more than thirty at most could be

found,—about ten per cent. or less. No other damage was reported and none observed.

In Royston, a somewhat lesser percentage of chimneys seemed affected. Nothing further was reported in this village.

The cemetery near Cumberland was visited and closely inspected. No damage appeared, though some of the stones were quite unstable. There were a goodly number of vertical gravestones in this cemetery, which is quite large and well kept and evidently lies on deep gravelly soil.

(d) *Comox Lake*:

The disturbance on this lake was at the end farthest from Cumberland—the south-west end. Here, on the north shore, is situated the camp of the Comox Logging and Lumber Co. The camp is an extensive one, resting partly on the shore, partly on a raft, as shown in Fig. 37. Across the narrow end of the lake, say 1,000 feet distant, an old shack stood on a gently sloping beach with a stretch of sand, variously estimated as from 100 feet to 100 yards in width, leading down to the water which is, of course, not tide-water. At the time of the earthquake, this beach disappeared. The water rushed into the void, receding from the camp on the other side of the lake, so that the raft "bumped on the bottom." Then it came back as a high wave. A man on the wharf, seeing it coming, ran for higher ground and only just got away, the water surging about his legs.

The wave washed inland about 100 yards, as shown by debris on the roadway. Mooring piles in the harbour were popped out and washed ashore in every case but two. A twenty-foot motor boat was carried inland forty-five feet and lodged in the bushes. A heavy donkey engine on the wharf was thrown into the lake. It is stated that the new piles, now being driven, are eighty feet long, to give the same above-water stand as was given previously by thirty-foot piles.

On the far side of the lake, the shore is now a precipitous drop, cutting under the front of the old shack as shown in Fig. 38. Soundings made on July 7 show that the water is now 33 feet deep at the shore line. The beach has disappeared for a length of approximately 300 yards. Trees formerly on the beach now stand in deep water or are canted over almost at right angles from the bank and float partly submerged.

This seems to have been a tectonic drop. If it had been merely a slump, the first wave would have been toward the camp, not away from it. Moreover, at this point, the shore is fairly level for a considerable distance back toward the mountain. A valley leads from this end of Comox Lake, south-westerly to Alberni, a fact which may or may not be significant. There is a possibility that a disturbed fault leads down this valley, but no evidence could be obtained in such wild country.

Landslides were visible in several places at this end of the lake, but no disturbance seems to have affected the north-east end. However, there are no structures there to be damaged until one reaches the small village of Bevan. Here the chimneys seemed, in general, to be old and in poor repair. Nearly all were visibly damaged.

(e) *Courtenay*:

According to the estimate of the Fire Chief, Mr. Cleland, about 25 per cent. of the chimneys were damaged in Courtenay. These were mostly in the central part of the town, known as "The Orchard." Some of these were on frame buildings, others on brick or brick veneer structures. See Fig. 18. Fig. 16 shows the hole in the roof of the Elementary School, caused by the fall of a large chimney. Fig. 15 shows the damage resulting in the class-room. Fortunately, the earthquake occurred on a Sunday morning. A large chimney on Hotel Courtenay also fell through the roof, causing considerable damage in one room and lesser damage in others. No one was injured by the fall of any of these chimneys.

There were some plate glass windows cracked, many stores lost heavily from broken dishes and bottles. The heaviest breakage loss seems to have occurred in the liquor store, where many bottles were broken. Several barrels of broken glass was the only reported salvage in this case.

No land cracks appeared in or near Courtenay except on the "Dyke Road." This does not afford much indication of earthquake violence and none of tectonic drop. The road at this point is a fill over a marsh. (The spot is marked D on the Courtenay-Comox map, Fig. 4). The road at this spot crosses the wide delta of a small creek. The side of the road simply slumped off for a distance of a hundred yards or so.

At various points near Courtenay and Comox, where houses were built on deep soil on sloping hillsides, the foundations gave way and the houses slipped off. In one case, a house under construction was completely thrown from its supporting timbers. The tremors in this region were severe.

(f) *Comox*:

About 40 per cent. of the chimneys in Comox seemed to have been damaged but no local estimate was obtained. It was observed that those on one side of the road seemed to have been damaged more generally than were those on the other.

At Saint Joseph's Hospital—a well-constructed, brick veneer building—no cracks appeared in the outer walls, although plaster was cracked in the interior and many articles, statues, etc., were thrown down. A large statue of Saint Joseph, standing in a niche over the entrance doorway, was turned 45° contra-clockwise, as has been reported previously. No other damage was caused in the building or in the cemetery which adjoins the grounds.

(g) *Goose Spit*:

Lying partly across the mouth of Comox Harbour is Goose Spit, on which is established a naval training base, HMCS. Naden II. This narrow neck of land received a severe shaking. The water mains were disrupted and the septic tank was cracked, necessitating the evacuation of the cadets until July 20.

Referring to the sketch map (Fig. 4), it will be noted that the coast line from Courtenay to Royston runs south-east and lies roughly parallel with the right-hand side of the map. A submerged sandbank known as Comox Bank or Kelp Bar runs from a point to the right of Goose Spit (parallel to and just off the edge of the map) down to Denman Id. On July 5, Capt. Hicks of the "Princess Mary" took soundings over this Bar, finding a depth of 27 feet, where, according to his chart, the depth at that tide should have been 6 feet. This would be important if it were established. Referring to Fig. 1, it is to be noted that, at low-tide, it is necessary for steamers to go south around Denman Id. and back around the north end of Texada Id. to reach Powell River. If Kelp Bar has sunk as much as indicated by the above soundings, a scheduled service could be run directly from Comox to Powell River.

This matter being of considerable importance, the Hydrographic Survey is taking echo-sounding profiles in these waters. The Acting Hydrographer, Mr. W. K. Willis, states that a preliminary run failed to indicate any such changes in depth. A final report on this work is not yet available. The precise levelling to be done by the Geodetic Survey, as previously mentioned, will be carried in to Comox (but not to Goose Spit, no previous benchmarks having been placed thereon).

At the jetty on Goose Spit, the piles are very long. The tides are of the order of fourteen feet at this point. At the time of the earthquake, the jetty sagged toward its seaward end, due to a leaning forward of the piles, pulling the shore end outward about a foot. As this is a very heavy long jetty, the effect is indicative of considerable strain. A good view of the jetty at low tide appears in the background in Fig. 8.

Some time previous to the earthquake, Lieut. Saxon had marked on one of the piles the actual height attained by a "high-high-tide." After the earthquake, he marked the actual height attained at a given high tide. This second mark was eight inches above the earlier one and the "paper difference" between the two tides was two feet. This would seem to indicate that the jetty and the sea floor on which it stands had sunk about two feet eight inches, plus or minus, allowing for fluctuations from tide-table values.

On the inside of the little bay, south of the jetty, is built a very substantial skidway for taking barges and boats up the bank to a repair shop. This skidway was put out of commission by the earthquake, as is shown in Fig. 8.

Cement walls backing the targets at the shooting range on the narrowest part of the spit were cracked by the shock, as were the "obstacles" used in the commando training.

At various points on the spit, deep cracks appeared which were still very well marked on July 12. Running diagonally across the end of the spit, about a hundred feet behind the navigation light (see Figs. 4, 14) runs a trench about fifteen feet wide and more than a hundred yards long. There is a distinct down-drop of something like a foot (Fig. 33). This extends south-easterly and crosses the beach out into the Strait of Georgia (Fig. 34).

On the spit, at the points marked by two small dots (Fig. 4), are

the craters of two sand blows. These are 65 yards from the nearest high-water mark. The craters are about 5 feet across and 3 feet deep. The mud, sand and sea shells thrown up by the geysers are scattered uniformly over a circle 100 feet in diameter. Both craters are shown in Fig. 36 (the second beyond Lieut. Saxon and on a line with his shoulders), and a close-up of one appears as Fig. 35.

Those in the immediate vicinity of a subsidence or of a landslide report "tidal waves" of which the estimated heights range from six to forty feet. Undoubtedly, these waves *were* generated in the various localities, but there seems to be no evidence of any large "tidal" waves anywhere on the coast or on the lakes. On Goose Spit there is some evidence that there was a wave, and that it was not very large.

(h) *Merville*:

Although the writer passed twice through Merville, in company with Mr. DeGraves, no investigation was made other than to note that many chimneys were broken all along the road from Courtenay to Campbell River. However, a letter from a farmer, Mr. H. R. Treherne, gives some interesting details. He writes:

> I was deeply interested in the report of your recent visit to Courtenay, in this week's *Free Press*. I believe I can clear up some of the questions that appear to be of great value to you:
>
> (1) The quake came from the straits.
>
> (2) There was absolutely no noise preceding the quake.
>
> I live in the Kitty Coleman District and my land runs down to the sea and faces approximately east. I was working on a fence and facing the sea, when suddenly, down the hill, the earth looked like a large snake coming up the hill, yet where I was standing was perfectly still for a second or so. After the tremor reached me, the roar commenced, tops of trees fell and bedlam was let loose. You can rely upon this information as I am not of the imaginative or hysterical type.

This dramatic account of what must have been an interesting, if somewhat terrifying, experience raises a point which may be discussed here. The account states that, until the wave reached him, there was no noise, no preceding roar. The same report is given by Mr. Peyton (Wireless Operator on the "Cardena"), regarding his observations at Abbotsford in the Fraser Valley. He says that, on previous occasions when they had experienced an earthquake of much lesser intensity at his home (where he was at the time of this earthquake), the cows were disturbed and the chickens (and even the partridges)

made noises indicating their alarm. In this case, there was no noise until the house shook, and even then there was no subterranean roar. The cow lay, placidly chewing her cud, and the chickens were undisturbed in their yard; no partridges were heard.

On the other hand, reports from nearly all other places indicate that there was a roaring noise from beneath the ground, before the shaking began and continuing throughout the earthquake. These noises were said to have been very pronounced on Read Id. Newspaper accounts seemed to indicate that these noises were heard there for some time after the shock and that the residents were, on that account, apprehensive. A reply to a direct question, given by Constable MacAlpine in a letter dated August 6, states that the noises were heard only at the time of the earthquake (see Section 111).

(i) *Campbell River*:

In this town, about 75 per cent. of the chimneys were overthrown. Goods were damaged in falls from shelves. Crockery and glassware were broken. Windows were cracked. Considerable damage, due to falling chimneys, was reported from the Willows Hotel.

Near Campbell River a fairly steep slope, covered with soil, grass and trees, rises from the landward side of the highway. Several slips occurred on this slope. At one place a house (foundations, lawn and garden, complete) slipped down and forward toward the road for a distance of about five feet. This gave rise to the widely-circulated report that a "hill had shifted 30 feet."

Mr. Underwood, the Ranger, lives in a house on the shore. He came out on the lawn as the earthquake struck and saw several water spouts rise in the strait. At Painters in Duncan Bay, a few miles north of Campbell River, there was "a boiling up of black mud, making bulges in the bay of about the size of an automobile." At this point most of the chimneys were damaged. One or more were rotated but it was not possible to determine the sense of rotation, clockwise or contra-clockwise, as they had since been repaired.

Campbell River is normally a clear stream. It became muddy at the time of the earthquake and was still about as muddy as the Fraser as late as July 6. Mr. Underwood states that, in the country back of Campbell River, there are many landslides. Two bridges on a road built on an old logging railroad embankment went out. A beach

disappeared in Buttle Lake, which was reported to have left a cliff 45 feet high. (Undoubtedly, this was the broken face of a slumped alluvial fan.) Mr. Underwood has furnished a report, giving details personally observed, of the damage inland in this region, which is the area designated by the second tentative location by the U. S. Coast and Geodetic Survey triangulation using the instrumental data.

(j) *Quathiaski*:

This village on Quadra Id., just across the channel from Campbell River, exists for and because of the B. C. Packers' cannery. The manager reported that no damage had occurred there except for goods broken on being thrown off shelves in the store, crockery and glassware broken in houses and some chimneys injured. At the cemetery north of the village no damage of any kind could be observed on July 6.

(k) *Rebecca Spit*:

On the east side of Quadra Id. lies Drew Harbour guarded on the side by Rebecca Spit. Here, marked changes occurred in the spit and, presumably, in the water depths adjacent in the harbour. These are shown in Figs. 30, 31, 32. A diagram of the spit, copied from the British Admiralty Chart, No. 2870, is reproduced herewith. (Fig. 6).

Fig. 32 was taken with the camera facing south at the point marked D on the larger scale section of the chart. (Fig. 6.) Fig. 31 was taken from a position C on the beach, on the harbour side of the spit, with the camera facing north. Fig. 30 was taken from a point a little south-east of point B, looking along a trench about 100 yards long, cutting across the spit and having a deep sand blow near its centre. The camera was facing north-west.

It is to be noted that Fig. 31 shows a series of drops toward the harbour side of the spit. All the drops which paralleled the long axis of the spit showed a drop toward this same side. This was the case, even with regard to those on the narrow neck of land at D (Fig. 32). This is in contrast to the slumps on Maple Guard Spit, which showed a drop toward both sides of the spit, as well as cross, down-dropped trenches.

The series of drops shown in Fig. 31 continued to the beach and at that point the shore dropped off into deep water at once. It may be conjectured that any deepening of the waters about Rebecca Spit

is confined to Drew Harbour. As echo-soundings are believed to have been previously made in this harbour it would be of value from a scientific point of view to have new profiles made though it is believed that any changes found will be in the nature of increases in depth. As the drop on the beach totals ten or twelve feet, it is possible that quite marked changes may be found in Drew Harbour.

(1) *Read Island*:

The observations on Read Id. were made by the B. C. Police. Photographs taken by them are reproduced as Figs. 39, 40, 41, 42. These were all taken on a farm owned by Mr. S. K. Marshall. The position of this property is indicated approximately by the X shown in the smaller scale part of the sketch map furnished herewith (Fig. 6).

The report made by Skpr. A. L. Frost, of the Campbell River Detachment, reads, in part, as follows:

For the information of the Department, I would like to state that the damage caused by the earthquake was indeed very severe to this man's property.

An area of about 12 acres was almost completely devastated. Parts of his orchard and oat field have sunk between 30 and 40 feet. This sunken area is about 250 yards long and 150 yards across and part of it is forming into a small lake. Crevices 10 to 20 feet across extend for several hundred yards from this sunken area into the woods. A bluish clay has been pushed up to the surface in several places.

Marshall's place is situated near Burdwood Bay, approximate Latitude 50 degrees 10 minutes North, Longitude 125 degrees 6 minutes West, Admiralty Chart 2870.

An added report by Constable MacAlpine of the Campbell River Detachment reads, in part, as follows:

(We) made a patrol to Read Id. and surveyed the damage which is beyond words to correctly express and describe . . . Several persons were interviewed in the immediate area and all heard a very distinct rumbling or noise, seconds prior to the quake.

On receipt of this report and the photographs, a letter was sent to Constable MacAlpine, under date of Aug. 3, in which the following definite questions were asked:

There is one further vital point on which we should like direct information. In all these earth disturbances, was there any case of an absolute down-drop of a previously flat area? In other words, were these slumps on slopes, which slipped sideways into a ravine, gully or down-hill; or were they bounded on

all sides by slump cracks which face inward to a depression? If some of each type were found, which were the more extensive? In the photograph of the orchard, for example, it appears as though the ground is on a hillside, the surface of which slipped downward.

One other point: Your report states that a noise or rumbling was heard prior to the quake. The newspaper reports indicate that those noises have been heard as late as, say, July 25. Are those rumblings still being heard?

The reply, dated August 6, reads as follows:

In my opinion, all of the disturbances on Read Island were absolute down-drops from normally flat land. The area concerned would be called flat although there might be a slight irregularity in the surface of small knolls perhaps two or three feet in height. There was no indication whatsoever of side slip in this surface. One peculiarity is the fact that, although there are faults extending into the new-growth forest, the damage was confined to the area under cultivation.

With reference to the question on noise and rumbling, I made mention of the fact that the rumbling was heard prior to the quake, as this was general in the Read Island area. Newspaper reports of subsequent rumblings can be discredited. At no time did the patrol hear noises nor can any information be obtained of residents hearing any rumblings since the quake.

According to newspaper accounts accompanied by a picture of the conditions shown in Fig. 40, some of the "cliffs" (really faces of a down-drop) were "thirty feet high." Assuming the oats, in head, to be abount two feet high, one can readily see that the down-drop near the centre of Fig. 40 might easily be as much as twenty feet. It is possible that the face was even greater in the near foreground of the same picture.

It must be concluded that the damage on Read Id. is due to a down-drop of the foundation rocks. The promontory forming the southern tip of Read Id., south of Marshall's farm, is shown as mountainous, with peaks about 600 feet high. Immediately north of the farm, the terrain is also shown as high, with peaks up to 800 feet. Burdwell Bay, on which the farm lies, forms one indentation of the east coast, defining a low-lying valley, which extends across the neck of the promontory to another long bay on the west of the promontory, opposite Burdwell Bay. It is in this valley that these marked evidences of serious earthquake action are located.

12. *Summary and Conclusions*:

One of the most severe earthquakes of which any report can be obtained, which has affected any part of Canada within historic times,

occurred along the central east coast of Vancouver Island at $10^h\ 13^m\ 19^s$ a.m., P.D.T., on Sunday morning, June 23, 1946. The tremors were well recorded on seismographs at all stations in North America and excellent seismological records were also obtained from a number of stations in Europe.

The epicentre, tentatively designated by the triangulation from seismograph records, is at Lat. 49°.9 N., Long. 125°.3 W., a point about ten miles S.S.W. of Campbell River. This position and also the focal time given above are subject to minor amendment when the collected seismograms are studied later at the Dominion Observatory, where they are now being assembled.

A field study of the earthquake indicates that the epicentre is not even approximately a point, but is certainly a line extending along the eastern edge of Vancouver Id. from Deep Bay, opposite the south end of Denman Id. to Campbell River, and that parts of Quadra Id. and Read Id. are also affected.

The tremors continued (at Deep Bay, for example) for about thirty seconds. As nearly as could be learned, this was the estimate of reliable observers throughout much of the main epicentral region above designated.

In addition to broken chimneys, damaged goods in stores, broken crockery and glassware, windows, etc., there were marked changes in the land, particularly at Maple Guard Spit which flanks Deep Bay, at Goose Spit and at Drew Harbour on the east side of Quadra Id. and also near Burdwood Bay on the east coast of the southern promontory of Read Id. Cracks many feet in depth and up to eighteen inches in width opened up for lengths up to several hundred feet on the sand spits. An area of flat land, fifteen to twenty acres in extent, was down-dropped in level, cultivated fields on Read Id. Some of the faces of the drops were as much as twenty to thirty feet in depth.

At many places along the coast from Deep Bay to above Campbell River, water spouts were seen, which were described in some cases as thirty feet in height. These left permanent records on the sand spits, in the form of craters or "sand blows", which varied from a few inches across to craters five feet in diameter and three feet deep, after several weeks of exposure to rain. At the time of the earthquake some of these "could not be bottomed with a twelve-foot pole".

In many places the coastal waters were found to have increased in depth just off shore, by measured amounts up to 100 feet. A beach disappeared at the west end of Comox Lake, leaving a measured water depth of 33 feet where, previously there had been a beach, well above water. No report, authenticated or otherwise, indicates any place where a rise in the ground occurred, or where marine depths were lessened, except for a long welt which appeared on the beach at Westview, on the mainland south of Powell River. It is believed that all marine depth changes will be found to be in the nature of increases.

In addition to the epicentral region of which no doubt is entertained, there is another section which may have participated in the true tectonic shock. This includes Powell River (unlikely), the Alberni Canal opposite Franklin Creek, and some inlets near the outer end of Alberni Canal (unlikely).

On the Alberni Canal opposite Franklin Creek, considerable changes in depth certainly occurred near the shore, and seem, according to some soundings made, to have been found also in the channel. More than a mile of telegraph cable was lost at this point by the C.P.R. Telegraphs. Their soundings indicated increases in depth of more than 100 feet at some points.

There were many landslides, not only in the primary and secondary epicentral regions, but on most of the lakes on Vancouver Id. and even in the Fraser Valley, more than forty miles east of Vancouver. In many cases, an alluvial fan, extending from the steep rocks bordering the shores of these lakes and resting with its submerged outer rim on the marginal shelf, slipped off into deep water, leaving a steep cliff face, sometimes as much as thirty feet or more in height, at the point where the fan broke from the shore. Local waves of some violence occurred at such points, but general "tidal waves" did not result. Seiches of moderate height were observed for some hours on many of the lakes.

One man, Capt. Daniel Fiddler, was drowned off Maple Guard Spit when his dinghy was overturned at the time of the earthquake. His body was recovered after about two weeks. An employee of the B.C. Packers' plant at Kildonan was operating an ice crusher at the time of the shock. The piles supporting the front end of the wharf slumped off into deep water and the wharf sagged. He was thrown

into the water with the crusher, but was rescued with no more serious injury than a broken shoulder. A man in Seattle is said to have died of heart failure due to the shock. In many places residents suffered minor injuries from broken glass, etc. There were no fires resulting from the earthquake.

Damage, becoming notably less with increasing distance from the epicentre, was reported throughout Vancouver Id. and adjacent territory on smaller islands and on the mainland. The tremors were felt as far south as Portland, Ore., and as far east as Kelowna in the Okanagan Valley. The point farthest north, from which a report was received indicating that anyone had felt the tremors, was Smithers, but it was not a general experience north of Ocean Falls and Bella Coola. The evidence is conclusive that this earthquake was not associated with the Queen Charlotte Ids. nor with any submarine fault off the continental shelf in the Pacific.

In general, there were few cases of rotation of chimneys or gravestones; only ten authenticated cases are recorded. Of these, all lying south and east of a line associated with maximum disturbance (up the Alberni Canal to Alberni, across the height of land to Qualicum Beach, thence through Deep Bay and up the coast to Campbell River, Quadra Id. and Read Id.) turned clockwise. All north and west of that line turned contra-clockwise. No significance can be attached to this fact, since the data are so few.

The earthquake was, in general experience, preceded and accompanied by a heavy subterranean roar. At several places, however, competent observers indicate that there was absolutely no sound until the heavy shock occurred.

Unique among earthquakes of this magnitude, only one aftershock was recorded. This was felt generally throughout the main and secondary epicentral districts but was not sufficiently strong to cause any damage. One other slight shock was reported as having been felt by three people and still another by two observing together. Except for these three light tremors, no aftershocks have been reported to the date of this writing.

Dominion Observatory,
Ottawa, Canada, September 9. 1946.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

Leonardo da Vinci

THE great Italian artist and scientist, Leonardo da Vinci, who lived from 1452 to 1519, is credited with first explaining that beautiful phenomenon known as the "old moon in the new moon's arms". As well as correctly interpreting the faint light on the dark side of the moon, he made in his voluminous note-books other astronomical remarks that are noteworthy. Some of them show a shrewdness of observation which is lacking in many people five hundred years later.

We quote material from the vast collections of his note-books, as compiled under different subjects by MacCurdy, in the two-volume work, *The Note-books of Leonardo da Vinci,* arranged by Edward MacCurdy. Jonathan Cape, London, 1938. Vol. 1, pp. 291-314, Astronomy.

It is not always possible to tell how much in Leonardo's note-books was his original idea, and how much was based on his extensive knowledge of classical thought. As MacCurdy says, "To estimate aright the value of his researches in the various domains of science would require an almost encyclopaedic width of knowledge." One cannot fail to admire this versatile genius who lived before the invention of the telescope and our present day ideas of the solar system as developed by Copernicus, Galileo, Kepler and Newton.

Make glasses in order to see the moon large.

. . . . . .

When the sun during an eclipse assumes the shape of a crescent, take a thin plate of iron and make a small hole in it, and turn the face of this plate towards the sun, holding a sheet of paper behind it at a distance of half a braccio, and you will see the image of the sun appear on this sheet in the shape of a crescent, similar in form and colour to its cause.

. . . . . .

The moon has every month a winter and a summer.

And it has greater colds and greater heats and its equinoxes are colder than ours.

The preceding quotations are from the manuscript known as the *Codice Atlantico,* in the Ambrosian Library, Milan.

The moon is not luminous in itself, but it is well fitted to take the characteristics of light after the manner of the mirror or of water or any other shining body.

. . . . . .

It may be readily understood that every planet and star is farther away from us when in the west than when it is overhead, by about three thousand five hundred [miles] according to the proof given at the side [of the page];

. . . . . .

The stars are visible by night and not by day owing to our being beneath the dense atmosphere which is full of an infinite number of particles of moisture. Each of these is lit up when it is struck by the rays of the sun and consequently the innumerable radiant particles veil these stars; and if it were not for this atmosphere the sky would always show the stars against the darkness.

. . . . . .

Some say that the sun is not hot because it is not the colour of fire but is much paler and clearer. To these we may reply that when liquefied bronze is at its maximum of heat it most resembles the sun in colour, and when it is less hot it has more of the colour of fire.

. . . . . .

Whether stars have light from the sun or in themselves:

It is said that they have light in themselves, since if Venus and Mercury had no light of their own, when they come between our eye and the sun they would darken as much of the sun as they cover from our eyes. This however is false, because it has been proved how a dark object placed against a luminous body is surrounded and entirely covered by the lateral rays of the remainder of this luminous body, and so it remains invisible. As is shown when the sun is seen through the ramification of leafless trees in the far distance, these branches do not conceal any part of the sun from our eyes. The same thing happens with the above mentioned planets, for though they are themselves without light they do not as has been said cover any part of the sun from our eyes.

It is said that the stars at night appear most brilliant in proportion as they are higher up, and that if they have no light of their own the shadow cast by the earth when it comes between them and the sun would come to darken them, since these stars neither see nor are seen by the solar body.

But those who say this have not considered that the pyramidal shadow of the earth does not reach many of the stars, and that in those which it does reach the pyramid is so diminished that it covers little of the body of the star, and all the rest is illuminated by the sun.

The foregoing group of quotations is from manuscripts in the Library of the Institut de France.

The moon has no light of itself but so much of it as the sun sees, it illuminates. Of this illuminated part we see as much as faces us. And its night receives as much brightness as our waters lend it as they reflect upon it the image of the sun, which is mirrored in all those waters that face the sun and the moon.

The above is from the Arundel manuscript in the British Museum.

And in the manuscript *Quaderni d'Anatomia,* in the Royal Library, Windsor, is written—

The sun does not move.

From the Leicester manuscript, owned by Pierpont Morgan, is another reference to the phenomenon of earthshine.

When the eye in the east sees the moon in the west near the setting sun it sees it with its shaded part surrounded by the luminous part; of which light the lateral and upper portions are derived from the sun and the lower portion from the western ocean, which still receives the solar rays and reflects them in the lower seas of the moon, and moreover it imparts as much radiance to the whole of the shaded part of the moon as the moon gives to the earth at midnight, and for this reason it does not become absolutely dark. And from this some have believed that the moon has in part a light of its own in addition to that which is given it by the sun, and that this light is due to the cause already mentioned, namely that our seas are illumined by the sun. (Diagram) moon, solar body, earth.

. . . . . .

Some have believed that the moon has some light of its own, but this opinion is false, for they have based it upon that glimmer which is visible in the middle between the horns of the new moon, which appears dark where it borders on the bright part, and where it borders on the darkness of the background seems so bright that many have assumed it to be a ring of new radiance which completes the circle where the radiance of the tips of the horns illuminated by the sun ceases.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Why Doesn't the Fire Burn?

Many years ago the present writer was much impressed by a description in *Nature* of a fire-walking performance on an island in the Pacific Ocean. It seemed incredible and yet the evidence could not reasonably be denied. In a recent book (London, 1945) entitled "From a South Seas Diary," the author, Sir Harry Luke, who was Governor and Commander-in-Chief of Fiji and the High Commissioner for the Western Pacific, (1938-1942), under date of February 28, 1939, reports what he saw on Mbengga, one of the lesser islands of the Fijian group, as follows:

> In the afternoon we saw the fire-walking, which is a specialty of the villagers of Nandaku-Ni-Mbengga in this island. Large stones (which are never used again) were heated in a circular pit with a wood-fire until they were white-hot; then the logs were removed with a good deal of ceremony and chanting. To prove their heat, a handkerchief was thrown on the stones and promptly burst into flames. Meanwhile those who were to take part in the actual fire-walking were concealed in a special hut, undergoing the preliminary ritual preparation. This completed, they came out, walked quickly (without running) once round the pit, which is about fifteen feet long, then cooled their feet on bundles of grass and leaves which were now thrown on the stones by the other villagers. We inspected the soles of one of the walkers and could see no sort of injury, but the man was tense and quivering. I fancy the immunity from pain is caused by a form of exaltation similar to that which prevents dervishes from bleeding when they put skewers and bodkins through their flesh after reaching the state of religious and hypnotic ecstasy they call *hal*. I have many times seen such performances at close quarters, in Asia Minor, in Syria and especially with my old dervish friend Sheikh Haj Mohammed in his Kirklar Tekyé in Cyprus, have observed the painless transfixion of cheeks, neck and skin of the breast by skewers, and have verified by sight and touch that these transfixions were completely bloodless.
>
> The fact that the fire-walkers of Mbengga prepare themselves for their ordeal by a religious ceremony lends substance to my belief that this ceremony induces in them a state of ecstasy similar to that of the dervish *hal*.
>
> The business ended with a faintly comic anti-climax, when the villagers, evidently not wanting to waste good heat, put a little pig on the stones to roast before they covered them with earth.

For Sunday, August 18, 1941, the *Diary* has the following entry:

> Saw the Indian fire-walking ceremony at the Suva suburb of Samambula, performed by southern Indian Hindus in honour of the Fire Goddess Maha Mari.

The devotees, who by fasting and other religious exercises had worked themselves into a state of ecstasy and had come in procession from miles away, looked dazed when they arrived, their faces smeared with yellow turmeric. Nevertheless, they walked without undue haste and without injury over a bed about twelve feet long of red-hot ashes some six inches deep.

A decided mystery. Ecstasy may prevent the feeling of pain, but a stone at a high temperature ordinarily will burn.

C. A. C.

ARATUS, THE GREEK POET

A member writes for information regarding the Greek poet Aratus. He was born at Soli, in Cilicia, and flourished about 278 B.C. It is in his poem "Phenomena," or "Astronomy," that there occurs the phrase, "for we are his offspring," alluded to by St. Paul in Acts xvii. 28. "This remark, which is quoted both by Eusebius and by Clemens of Alexandria, appears to have largely contributed to the esteem in which Aratus was held by both Christian and heathen philosophers." (C. L. Prince).

The copy of Aratus in the David Dunlap Observatory library contains a literal translation of the "Astronomy" and the "Meteorology" by C. L. Prince and was printed in 1895. It is in prose although most of the translations have been in verse. The "Astronomy" in this volume occupies 21 pages.

Herewith is the first paragraph:

Let us dedicate our lay to Zeus, whom we should never leave unadored, for he is ever present at all the assemblies and gatherings of the people, as well as at the sea and its harbours. In all places we are dependent upon him. *For we are his offspring.* Ever kind to us, he reminds us of our wants, and urges us to toil for our necessary food; likewise he appoints the time for breaking up the clods of earth with the oxen and the ploughshare; also the most favourable time for putting the plants into the ground and scattering the seeds into the furrows. He, distributing the stars, arranged the constellations in the sky. He placed them to indicate that season of the year which should give the plainest instructions to men at what time all vegetation should burst forth. Him, therefore, both first and last, it should be our endeavour to please. Hail Father! Marvellous Wonder! Vast Benefactor of Mankind! Himself the survivor of a former age. All you charming Muses salute him! If not asking too much I pray you to inspire my song to make mention of the stars. These, indeed, are many, existing everywhere in the sky, and day by day continually revolving from age to age.

C. A. C.

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WAVE-LENGTH STANDARDS FOR RADIAL-VELOCIT DETERMINATIONS, I*

By R. M. PETRIE

ABSTRACT

Wave-length standards are determined for the spectral interval F4 to K8 for high (11 A/mm.), and moderate (30 A/mm.), dispersions. The high dispersion standards are based upon 89 spectrograms and those for moderate dispersion upon 85 spectrograms. Spectra of the sky, moon, planets, and Standard Velocity stars are used in conjunction with the *Rowland Table* of solar wave-lengths in selecting the standards. Radial velocities from 112 high-dispersion plates and 113 single-prism plates show that these wave-lengths standards give a system homogeneous throughout the spectral interval, and in very close agreement with that of the General Catalogue.

INTRODUCTION

For some time there has been under review at Victoria the wave-length tables currently used in reducing spectrograms measured for radial velocity. A few years ago there arose the need for radial-velocity standards for spectra of relatively high dispersion and, in compiling these, certain precepts were followed in order to obtain homogeneous velocities for different spectral classes and to attempt to place them upon a common origin. It became desirable, then, to examine the existing wave-length tables, *i.e.* for single-prism spectra, to ensure that they met the requirements laid down for high dispersion. The investigation has been completed for high, and moderate, dispersions for spectral types F4 to K8 and is being extended to the A stars and to low-dispersion spectra. It seemed well to publish now the completed results and to discuss, in some

*Contributions from the Dominion Astrophysical Observatory, No. 4.

detail, the guiding principles and methods used, especially since the wave-lengths given here are required in the extension of the system on a homogeneous basis to other spectral types. It is expected that other lists of standards will appear as they are compiled.

General Considerations

The ultimate aim of those engaged in radial-velocity observations is to determine radial velocities sensibly free from systematic errors and verified by line-of-sight motions derived from geometrical and dynamical studies, such as the motions of members of the solar system. That this object has been but imperfectly realized is demonstrated by the systematic differences known to exist among observations from different institutions,[1] and is suggested by the existence of a *K*-term in statistical studies of the solar motion and galactic rotation.[2] While the *K*-term may have a physical cause, which does not refer to errors of measurement, it is obvious that the explanation will remain obscure until we are sure that adopted wave-lengths do not, because of blends, Stark effect, etc., lead to erroneous velocities but give the same velocity origin for all spectral types. This is a formidable problem, the difficulties of which have been discussed by many workers and summarized in the introduction to the Lick *Catalogue of Radial Velocities*.[3] In essence the matter rests as follows: the reliability of effective wave-lengths for spectra close to G0 is proved by comparison with computed velocities in the solar system, but the extension of these wave-lengths to later spectral types and the standards employed in O, B, and A stars cannot be verified in this way.

It is believed, however, that the difficulties may be resolved and that test objects for spectral types other than G do, in fact, exist. The test objects proposed by the writer are, first, stars which are members of moving clusters and, secondly, stars which form components of visual binaries known to be physical systems and in which one member is of spectral type near G0.

The space motion of a moving cluster, relative to the sun, may be computed from the total proper motion and parallax of one, or

[1] See, for example, *P. Lick O.*, vol. 18, p XI, 1932.
[2] *Handbuch der Astrophysik*, vol. 7, p. 601 *et seq.*, 1936.
[3] *P. Lick O.*, vol. 16, p. XI, 1928.

more, of its members. We may then predict the radial velocities of all the members from observations which are quite independent of radial-velocity data. Theoretically this method of supplying verification of radial velocity determinations is very attractive, but unfortunately the parallax and proper motion data are insufficiently precise for our purpose except for one cluster, the Ursa Major group. And, more unfortunate still, the bright A stars of this cluster, in the direction of Ursa Major, exhibit rather large positive residuals in radial velocity. Until this phenomenon is better understood one is reluctant to use many of the members of this cluster. But the moving clusters may help in another way since we may compute their space motions from radial-velocity data.[4] If we determine the radial velocities of cluster members having spectra similar to the sun, and using wave-length standards proved by comparison with solar system velocities, we may then predict the radial velocities of all cluster members on the same system as that of the solar types. It is considered that this method will prove most valuable in extending wave-length standards on a homogeneous basis to all spectral types.

The visual binaries similarly may serve as secondary standards if one component, a solar type, is observed with wave-lengths proved from the solar system. The velocity of the other component, say a B, A, or K star, may then be computed.

The methods outlined above will, it is hoped, help to place effective wave-lengths upon a satisfactory basis and will, ultimately, be employed at Victoria for that purpose. Our immediate task, the compilation of effective wave-lengths for spectral types F4 to K8, is more simple since many solar wave-lengths may be expected to hold good over this range. It was decided to attempt to find wave-lengths so that the system would agree with that of the Lick Observatory and General Catalogue,[1] and defined by the Standard Velocity stars, provided that it could be shown that this system was homogeneous over the required spectral range. The Lick system was examined, therefore, to see whether it was free from a spectral-class velocity trend since the velocities are based largely upon solar wave-lengths. The velocities of stars of the appropriate spectral types were taken from the Catalogue as shown on the following tabulation.

[4]See for example, Smart, *M.N.* vol. 99, p. 175, 1939.

Test Group	No. of Stars	Spectrum Range
Taurus Cluster	12	F4 — G9
Ursa Major Cluster	16	F4 — K5
Visual Binaries	14	F4 — K4

For the Taurus stars residuals were formed from a cluster motion, relative to the sun, of 43.5 km./sec., while for the Ursa Major group the geometrical value, as given by Smart,[5] 19.1 km./sec., was used. In the visual binaries the velocity of the solar-type component was used and the small differential velocity due to orbital motion was neglected for the present. Individual residuals were plotted against spectrum and no indication of a spectral-class trend was evident. The mean residuals with their probable errors are as follows:

Mean Spectrum	Range	Mean Residual	No. of Stars
F5	F4—F7	-0.1 ± 0.5 km./sec.	13
G0	F8—G2	$+0.3 \pm 0.7$ "	9
G6	G3—G8	$+0.2 \pm 0.4$ "	11
K2	G9—K5	-0.3 ± 0.6 "	9

Despite the small number of test stars the result of this inquiry gives reason to believe the system of the Catalogue to be homogeneous over the range F4 to K5 and hence the Standard Velocity stars may be used with confidence in determining effective wavelengths for radial-velocity standards.

The work was commenced by measuring a large number of lines on a sufficient number of plates of Standard Velocity stars and including plates of the sky, moon, and planets. The mean velocity residuals, line by line, from the standard velocity, were plotted against spectral type so that one could at once eliminate those exhibiting a definite variation with spectrum (and in some cases with luminosity). For example compare the following residuals, determined from single-prism plates, given by the features λ4063.61 and λ4404.74.

Spectrum	λ4063	λ4404
F5	− 2.2 km./sec.	0.0 km./sec.
G0	− 0.6 "	− 1.0 "
G5	+ 2.9 "	− 0.2 "
K0	+ 6.0 "	− 0.6 "
K2	+ 10.2 "	− 0.6 "
K8	+ 10.9 "	+ 0.8 "

[5] *M.N.* vol. 99, p. 445, 1939.

It is evident that 4063 is quite unsuitable for general use, with this dispersion, while 4404 is reliable throughout the whole range. The variable features being eliminated those remaining were examined for the purpose of assigning effective wave-lengths. The *Revised Rowland Table*[6] was used as a basis but studies of the spectra of β Coronae Borealis,[7] α Persei,[8] and α Bootis[9] were consulted. The spectral features fall into three groups according to velocity behaviour, as follows: (*a*) lines which are relatively "pure" and for which solar wave-lengths, as given in the *Revised Rowland Table*, may be used; (*b*) lines which are blends but for which mean solar wave-lengths, weighted according to Rowland intensities, are satisfactory and (*c*) features which are constant over the spectral range but are composed of so many lines that the effective wave-lengths cannot be predicted from the solar table, and empirical values, based upon the measures, must be used. These three types are distinguished in the tables by the symbols, $\odot$, *m*, and *a*, respectively. It may be remarked that every effort was made to find suitable features valid over the whole spectral range but it was found necessary to include some standards of restricted applicability, especially in the lower dispersion list. To eliminate them would reduce the number of lines to the point where accidental errors of measurement might influence the results.

It must be emphasized that no attempt was made to force *exact* agreement between the individual line velocities and the adopted standard velocities. Each measured feature was studied independently and the object was to select the line, or group of lines, as given in the *Revised Rowland* and other tables, producing the feature measured on our plates. Except in the case of badly blended features the measured velocities were used as guides, rather than determining factors, in compiling the effective wave-lengths and every care was exercised to ensure that small velocity residuals did not interfere with one's judgment here. In other words, solar wave-lengths, and not adjusted values, are the basis for the tables. As an illustration of the method consider the line, due largely to neutral iron, at λ4404.7, as studied upon our single prism-plates.

[6] *Papers of the Mount Wilson Observatory*, vol. III, 1928.
[7] Hiltner, *Ap. J.*, vol. 102, p. 438, 1945.
[8] Dunham, *Cont. Princ. O.*, No. 9, 1929.
[9] Hacker, *Cont. Princ. O.*, No. 16, 1935.

The *Revised Rowland Table* gives the following lines contributing to the single-prism feature:

4404.279	Ti I	intensity	1
04.763	Fe I	"	10
05.035	V I, Fe I	"	1

which give a weighted mean of 4404.745. Since no other lines affect the measured feature this value was adopted even although there remained then a mean residual of −0.4 km./sec. To make small arbitrary adjustments in order to cause the residuals to vanish would introduce instrumental, and other, sources of error into the wave-lengths and prejudice our attempt to maintain the velocities upon a fundamental basis. It is better to evaluate and eliminate, separately, the instrumental sources of error and the effect of personal equation. Where empirical wave-lengths had to be adopted the measured residuals were, perforce, employed, in determining the wave-length. Such lines compose 15 per cent. of the high-dispersion table and 30 per cent. of the single-prism list.

It should be mentioned finally, in accordance with the recommendation of the *International Astronomical Union*,[10] that since the comparison line wave-lengths are laboratory wave-lengths, while the stellar lines are *Revised Rowland* values, the velocities are referred to the sun and contain the relativity displacement; or whatever other source of wave-length displacement which may be present in the solar atmosphere.

Radial-Velocity Standards for High Dispersion, F4–K8

The spectra used for wave-lengths in this section were obtained, almost entirely, with the two-prism spectrograph using a long-focus camera (II L) and a few spectra with two prisms and a medium-focus camera (II M). The linear dispersion on the II L plates is 11.0 A/mm. at $H\gamma$ and the slit-width ordinarily employed is 0.05 mm. The wave-lengths were measured on 89 spectra of the solar system and Standard Velocity objects, as listed in Table II, while 112 spectra are available for the final velocity comparisons. The final adopted wave-lengths together with the identifications of the principal contributing elements, and the spectral ranges over which they are valid are given in Table I. The wave-lengths are given

[10] *Tr. I. A. Un.*, vol. 4, p. 186, 1932.

to the nearest thousandth in accordance with general practice but the last figure is not, of course, very significant. The spectral range in good focus on the plates is from λ3930 to λ4528 so that this list is complementary to that prepared by Frost and Struve[11] for high dispersion.

TABLE I WAVE-LENGTH STANDARDS FOR HIGH DISPERSION

λ I.A.		Spectral Range	Identification	λ I.A.		Spectral Range	Identification
4045.804	*a*	F4–K0	FeI	4271.776	⊙	F4–K8	Fe I
63.554	*m*	F4–K8	FeI	74.808	⊙	F4–K8	Cr I
71.738	*m*	F4–K8	Fe I, V I	4307.859	*m*	F4–G0	Fe I, Ti II, Ca I
77.690	*m*	F4–K8	Sr II,La II, Y I	25.777	⊙	F4–K8	Fe I
4101.742	*m*	F4–G0	Hδ, Fe I	40.477	⊙	F4–K8	Hγ
32.051	*m*	F4–K8	Fe I	51.833	*a*	F4–K8	Cr I, Fe I, Fe II, Mg I
4235.591	⊙	F4–K8	Fe I	75.900	*m*	F4–K8	Fe I
46.838	⊙	F4–K8	Sc II	83.559	⊙	F4–K8	Fe I
50.799	⊙	F4–K8	Fe I	4404.763	⊙	F4–K8	Fe I
54.330	*a*	F4–K8	Cr I	27.262	*m*	F4–K8	Fe I, Ti I

The velocities derived from the adopted wave-lengths may now be compared with the standard system. The 26 spectrograms of the sky, moon, and planets give a mean residual,

$$\text{Observed} - \text{Computed} = +0.1 \pm 0.1 \text{ km./sec.}$$

The 63 spectrograms of six Standard Velocity stars give the mean residual,

$$\text{Victoria} - \text{Standard} = -0.2 \pm 0.0 \text{ km./sec.},$$

while 18 spectra of four additional stars compared directly with III-prism results of the Lick Observatory give

$$\text{Victoria} - \text{Lick} = -0.6 \pm 0.2 \text{ km./sec.}$$

The individual star comparisons are given in Table II. There is no indication of any spectral-class trend in the residuals and the values

[11] *Tr. I.A. Un.*, vol. 5, p. 193, 1935.

TABLE II. RADIAL-VELOCITY RESIDUALS WITH HIGH-DISPERSION STANDARDS

Star	Spectrum	Plates	Victoria—Standard km./sec.	Victoria—Lick km./sec.
ι Piscium	F4	7	+ 0.2 ±0.4	
α Persei	F5	14	− 0.3 ±0.1	
ϵ Leonis	G0	9	− 0.1 ±0.1	
β Geminorum	G9	9	− 0.1 ±0.1	
α Bootis	K0	12	− 0.3 ±0.3	
α Bootis*	K0	5	− 0.2 ±0.6	
α Tauri	K8	12	− 0.3 ±0.2	
χ^1 Orionis	G1	4		−1.2 ± 0.4
γ Tauri	G6	5		−0.1 ± 0.5
δ Tauri	G9	5		−0.3 ± 0.4
ϵ Tauri	G9	4		−1.0 ± 0.5

*Plates of IIM, dispersion at $H\gamma = 14.8$ A/mm.

are satisfactorily small. The final mean residual from the Catalogue system, based upon 112 spectrograms is between −0.1 km./sec. and − 0.2 km./sec. and it is so small that its exact value cannot be ascertained at present. Flexure and other instrumental effects remain to be evaluated and guiding error, personal equation, and accidental error of measurement all contribute to the final residual. It is particularly gratifying to find the agreement so close since no evaluation of the system as a whole was made until each line had been considered separately and its effective wave-length adopted. We may conclude that the values in Table I define a satisfactory homogeneous system for radial-velocity work with high-dispersion.

This list of wave-lengths will be employed in all our high-dispersion radial-velocity determinations in the ordinary region for spectral types F4 to K8.

RADIAL-VELOCITY STANDARDS FOR SINGLE-PRISM DISPERSION, F4 TO K8

The wave-lengths presented in this section are determined for single-prism spectra of moderate dispersion. Most of the plates were obtained with the IM combination giving a linear dispersion, at $H\gamma$, of 30.1 A/mm. but a few spectra were with the IL combination which gives 22.0 A/mm. at $H\gamma$.The slit width was 0.05

mm. Studies are being made to determine whether these standards are suitable for the lower dispersions and purities which must be employed more and more as radial-velocity work is extended to fainter stars.

The wave-lengths are based upon measures of 85 spectrograms of the sky, moon, and planets and of eight standard velocity stars as listed in Table IV while there are 113 spectra available for the final comparison. The procedure followed is that outlined above and follows closely the methods used in the high-dispersion studies. A large number of lines were selected as a preliminary list including those recommended by the *International Astronomical Union*.[12]

TABLE III. WAVE-LENGTH STANDARDS FOR SINGLE-PRISM DISPERSION.

λ I.A.		Spectral Range	Identification	λ I.A.		Spectral Range	Identification
3933.684	⊙	F4–K8	Ca II	4191.555	*a*	F4–G0	Fe I
68.494	⊙	F4–K8	Ca II	4202.093	*a*	G0–K8	Fe I, Ni I
4005.205	*a*	F4–K8	Fe I	50.466	*m*	F4–G5	Fe I
30.673	*m*	F4–K8	Fe I, Mn I	54.330	*a*	F4–K8	Cr I
45.827	⊙	F4–K8	Fe I	60.429	*m*	F4–K8	Fe I
63.607	⊙	F4–G0	Fe I	82.640	*a*	F4–K8	Fe I, Ca I
71.751	⊙	F4–K8	Fe I	4307.914	⊙	F5 K2–K8	Fe I, Ti II
77.710	*a*	F4–K2	Sr II, Fe I, Ti I	4404.745	*m*	F4–K8	Fe I, Ti I
92.512	*a*	F4–K8	Ca I, Fe I	15.137	⊙	G0–K8	Fe I
4101.742	*m*	F4–G5	H δ, Fe I	27.319	⊙	G0–K8	Fe I
18.702	*m*	G0–K2	Fe I, Co I	94.575	⊙	G9–K8	Fe I
43.772	*m*	G0–K0	Fe I				

The standards finally adopted together with identifications and valid spectral intervals are given in Table III. It will be noted that the original list has been so reduced that less than twenty lines are available for a given spectrum. It is better, however, to measure relatively few reliable lines rather than a large number of features which change in effective wave-length from star to star. The probable error given by a single line of average quality is ± 2.5 km./sec. and thus the probable error of a single plate would be about ± 0.6 km./sec. from the internal agreement. But the intercomparison of plates gives a probable error, for an average plate,

[12] *Tr. I.A. Un.*, vol. 5, p. 193, 1935.

of ± 1.3 km./sec. There is therefore no justification for measuring a large number of lines because external sources of error are more important than the accidental error of measurement. It is preferable then to use a restricted number of standards known to be reliable.

The velocity comparisons, using the standards of Table III are very satisfactory. The mean residual from 20 plates of solar system objects is

$$\text{Observed} - \text{Computed} = -0.2 \pm 0.2 \text{ km./sec.}$$

The 65 spectra of the eight Standard Velocity stars give a mean residual

$$\text{Victoria} - \text{Standard} = 0.0 \pm 0.2 \text{ km./sec.}$$

and 28 plates of five stars available for a direct comparison with Lick III-prism values give a mean residual

$$\text{Victoria} - \text{Lick} = -0.4 \pm 0.2 \text{ km./sec.}$$

The residuals for the individual stars are given in Table IV and, as before, there is no indication of a spectral-class effect. The final mean residual given by the 113 plates is − 0.1 km./sec., a very satisfactory result. It is of interest to note that the high-dispersion, and single-prism, standards define identical systems so far as present data go. The mean difference for ten objects observed in common is

$$\text{I Prism} - \text{II Prism} = -0.1 \pm 0.2 \text{ km./sec.}$$

TABLE IV. RADIAL-VELOCITY RESIDUALS WITH SINGLE-PRISM STANDARDS

Star	Spectrum	Plates	Victoria—Standard km./sec.	Victoria—Lick km./sec.
ι Piscium	F4	8	− 0.1 ± 0.6	
α Persei	F5	9	0.0 ± 0.5	
ϵ Leonis	G0	7	− 1.2 ± 0.9	
κ^1 Herculis	G3	8	+ 0.5 ± 0.5	
β Geminorum	G9	7	− 0.2 ± 0.4	
α Bootis	K0	11	+ 0.4 ± 0.2	
α Arietis	K2	6	0.0 ± 0.4	
α Tauri	K8	9	+ 0.9 ± 0.3	
ι Leonis	F4	2		0.0 ± 0.6
χ^1 Orionis	G1	7		− 1.3 ± 0.5
γ Tauri	G6	8		+ 0.4 ± 0.5
θ^1 Tauri	G6	4		+ 0.1 ± 0.7
δ Tauri	G9	7		− 0.8 ± 0.9

All Victoria radial velocities determined with the single-prism spectrograph and medium, and long, focus cameras (IM and IL), for spectral types F4 to K8 will be based, henceforth, upon the standards of Table III.

The Radial Velocities of Sixteen Stars

As a by-product of the study of the wave-lengths radial velocities are available for the Standard Velocity, and comparison stars, and are reproduced here in Table V. All of these stars have been observed before, of course, but in some cases this list makes a substantial increase in the number of existing determinations. The wave-lengths of Tables I and III are used so that these are the first published velocities upon the new system. A few of the IM plates had been measured previously and the results were published but they have been included with the new velocities in the list here. The entries in Table V are largely self-explanatory. The mean velocities and their probable errors were derived after the individual plate results had been weighted according to the number and quality of the lines measured, and the dispersion employed. It is expected that the individual plate results will be published elsewhere in the near future.

TABLE V. THE RADIAL VELOCITIES OF SIXTEEN STARS

Star	α(1900)	δ(1900)	Type	Mag.	Mean Radial Velocity	Instr.	No. of Plates	R
					km./sec.			
α Arietis	2^h01^m5	+22°59′	K2	2.32	−14.1 ± 0.4	IM	6	S
α Persei	3 17.2	+49 30	gF5	1.90	− 2.5 ± 0.2	IM, IIL	23	S
γ Tauri	4 14.1	+15 23	G6	3.86	+38.6 ± 0.3	IM, IIL	12	T
δ Tauri	4 17.2	+17 18	G9.	3.93	+38.1 ± 0.4	IM, IIL	11	T
ϵ Tauri	4 22.8	+18 58	G9	3.63	+37.8 ± 0.4	IIL	4	T
θ^1 Tauri	4 22.8	+15 44	G6	4.04	+37.8 ± 0.5	IM	4	T
α Tauri	4 30.2	+16 19	K8	1.06	+54.0 ± 0.2	IM, IIL	22	S
χ^1 Orionis	5 48.5	+20 15	G1	4.62	−15.5 ± 0.3	IM, IIL	11	U
β Geminorum	7 39.2	+28 16	G9	1.21	+ 3.1 ± 0.1	IM, IIL	16	S
ϵ Leonis	9 40.2	+24 14	gG0	3.12	+ 4.5 ± 0.3	IM, IIL	16	S
H.D. 88355	10 06.2	+13 51	F5	6.41	−17.4 ± 0.7	IM	6	
ι Leonis	11 18.7	+11 05	F4	4.03	−10.0	IM	2	
H.D. 111456	12 44.3	+60 52	F5	5.87	− 9.0 ± 1.5	IM	7	
α Bootis	14 11.1	+19 42	K0	0.24	− 5.3 ± 0.2	IM, IIL	29	S
κ^1 Herculis	16 03.6	+17 19	G3	5.34	− 9.4 ± 0.4	IM	8	S
ι Piscium	23 34.8	+ 5 05	F4	4.28	+ 5.4 ± 0.3	IM, IIL	15	S

S, Standard Velocity Star, T and U, members of Taurus and Ursa Major clusters.

SUMMARY

This investigation begins the task of placing the Victoria radial velocities, for all spectral classes, upon a homogeneous basis which is believed to approximate to a fundamental system. It was first established that the Lick system of radial velocities, for spectral types F4 to K5, is homogeneous and fundamental, and thus the Standard Velocity stars may be used to verify effective wave-lengths. Suitable wave-length standards based upon solar wave-lengths and verified by the Standard Velocity stars are derived, for the spectral range F4 to K8, for the high, and moderate, dispersions in use at Victoria. Velocities based upon these standards are found to agree very closely with those of the Lick system thus preparing the way for a fundamental homogeneous system embracing all spectral classes.

Dominion Astrophysical Observatory
Victoria, B.C.
May, 1946.

REVIEW OF PUBLICATIONS

Astronomie élémentaire, par Frère Robert, F.E.C., 3ème édition. 489 pages, 5½x8 in. Montreal, Imprimerie De La Salle, 949 rue Côté, 1946.

That this work has achieved success is shown by the fact that it has reached a third edition. The author remarks in his preface that although he has not been able to explain the beautiful theories which lie at the base of the most modern conquests of astronomy he has attempted to write a complete work, in a certain measure. He has not neglected the history of the labours of astronomers during the past centuries, since the study of man's long efforts in his search for truth is an instructive lesson in energy and perseverance. Then there is a certain body of astronomical knowledge which every cultured person should possess; this the author has aimed to explain in detail. He has also tried to outline the principles of astrophysics which continually reveal the unsuspected marvels of the universe.

Pages 9 to 308 are devoted to the solar system, 309 to 431 to astrophysics, 432 to 446 to Canadian observations and amateur astronomers of the province of Quebec. After this is an atlas of the celestial vault, including 12 circular maps of the stars, without star names, white on a blue background, and a key-map to each giving names and configurations.

Chapters I-II are devoted to preliminary ideas, III-VII to the earth, VII-XI to the sun, XII-XV to the moon, XVI-XX to the planets, XXI-XXVII to astrophysical notions.

The text is written in clear and simple language and there are numerous illustrations. It is elementary but the author does not hesitate to introduce calculations involving trigonometry and the principles of mechanics and probabilities. It may be remarked that on page 306 is given a statement of the noted observations of the meteor shower associated with the Giacobini-Zinner comet which were made at the Ebro observatory in Spain, October 9, 1933, and which led to the great interest in this shower recently.

A special and attractive feature of this work is the exercises and problems throughout it. There are numerous quotations from Homer, Victor Hugo, Louis Fréchette, Shakespeare, and many other writers. After each is a list of questions, often similar to an examination paper in literature. These are very interesting and clearly show how a knowledge of astronomy is required to understand the world's best writers.

Also, one must not forget the artistic little wood-cuts, with their appropriate legends, here and there in the book.

There are a few slight errors which a careful proof-reader might notice, but they do not detract from the scientific presentation of facts or the general impression of literary and artistic distinction.

C. A. C.

Total Eclipse of the Sun, May 20, 1947. 48 pp., 7x10 in., with two folding charts. Supplement to the *American Ephemeris,* 1947; prepared at the U.S. Naval Observatory, and for sale by the Superintendent of Documents, Government Printing Office, Washington 25, D.C. Price 25 cents.

This publication gives full details regarding the above eclipse, including general information, meteorological data, explanation of tables and maps. The two large-scale maps show that the path of totality crosses Chile (over Santiago), Argentina, Brazil, the Atlantic Ocean, Liberia, French Equatorial Africa, and ends in Kenya.

It has been announced that the National Geographical Society and the Army Air Forces will join in an expedition to the interior of Brazil to observe this eclipse. The site chosen is Bocayuva, about 400 miles north of Rio de Janeiro. American scientists from the National Bureau of Standards, the Lick, Yerkes and Georgetown observatories, and the Naval Research Laboratory will be included in this expedition. The period of totality will be almost four minutes and it will start about 9.35 a.m. Prospects are good for clear sky.

C. A. C.

An Album of Celestial Photographs, by A. L. Bedell, Lecturer in Astronomy, St. Louis University. 48 pages, 8¼x10¾ inches. Stiff paper cover. Published by the author, Box 1447, St. Louis 1, Missouri. Price, ordinary edition, $1.00; de luxe, $1.50.

In this booklet are excellent reproductions of 65 of the most remarkable and interesting photographs taken with the world's great telescopes, together with brief descriptions of the different objects. It is a fine album at a small price.

Any who wish to secure this publication may obtain further information from the office of the R.A.S.C., 3 Willcocks St., Toronto 5, Ontario.

C. A. C.

The Testing and Adjustment of Telescope Objectives, by H. Dennis Taylor. Pp. 95+VIII, 6x8½ inches. Sir Howard Grubb, Parsons and Co., Newcastle-upon-Tyne, England. 1946. Price 17s 6d.

This is a new, fourth edition, of a book first published in 1891. The continual demand for this work, for over half a century, is a guarantee of its usefulness as a standard manual of procedure.

The book describes various forms of lens systems, and the performance to be expected. The different aberrations and poor adjustments are outlined. Methods of testing the performance, and of determining to what extent any deficiencies are due to poor adjustment, are included. Throughout, the stress is on interpreting visual patterns in all testing, using simple auxiliary equipment. It is definitely a book that tells the observer how to proceed.

F. S. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The Smithsonian Institution—its First Hundred Years

James Smithson was an Englishman, born in 1765. He graduated from Oxford in 1786 and was elected a Fellow of the Royal Society the next year because of his proficiency in chemistry and mineralogy. He died in Genoa, Italy, in 1829. In the absence of heirs, his entire property was bequeathed "to the United States of America, to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." The proceeds of the estate were $550,000, and, after eight years of wordy discussion, Congress accepted the bequest and founded the Institution in 1846.

Its first Secretary was Joseph Henry, a physicist and a wise administrator. His outstanding contribution was in meteorology. Then followed Baird (1878-1887), a specialist in natural science; Langley (1887-1906), an astronomer and physicist; Walcott (1907-1927), a geologist; Abbot (1928-1944), an astrophysicist; and Wetmore, the present executive officer, a biologist. Thus, naturally, special attention has been given to all branches of science. During the later years valuable art treasures were presented to the nation, and, it is presumed, on account of the efficient management of the Institution they were put in its charge. In this way science and art are united in a treasure-centre at the service of the whole world.

From personal experience stretching over more than the latter half of the Institution's existence, the present writer can bear testimony to the generous manner in which the Institution dispenses its assistance, chiefly in the form of valuable publications, to workers in science.

In celebration of its centenary a handsome booklet full of information and beautiful pictures has been issued by the Institution. Let us make a few quotations from it:

> But why should an Englishman who had lived most of his life in France leave his fortune to the United States of America, a very young nation and

one in which he had never set foot? Here we are reduced to pure speculation, but it may be significant to note that Europe for years had been ravaged by war, whereas for America James Smithson doubtless visioned promise of lasting peace and freedom of thought and action. It is also interesting that the wording of Smithson's bequest bears a striking similarity to a phrase in George Washington's Farewell Address: "Promote, then, as an object of primary importance, institutions for the general diffusion of knowledge."—page 3.

In interpreting the meaning of the bequest, Henry bore in mind the fact that Smithson's sole interest in life was scientific investigation, and it therefore semed certain that in his will he intended to provide for the continuation of such work. For the increase of knowledge Henry's plan contemplated the support of scientific research, both through major projects at the Institution itself and through grants to outside workers in promising fields of investigation. The diffusion of knowledge he proposed to accomplish by publishing the results of original research in a series of memoirs and distributing them throughout the world.—page 7.

So for the past 100 years the Smithsonian Institution has utilized every available means for the diffusion of knowledge. Who can estimate the influence of such a program on the acceleration of science progress in America—indeed in the whole world? Only six years after the founding of the Institution, Secretary Joseph Henry wrote: "The worth and importance of the Institution is not to be estimated by what it accumulates within the walls of its building, but by what it sends forth to the world. Its great mission is to facilitate the use of implements of research, and to diffuse the knowledge which this use may develop." After the passage of 100 years this statement still expresses the Smithsonian ideal, and it will undoubtedly continue to do so in future years.—page 55.

C. A. C.

Square Degrees—Query

In reading a text-book on astronomy I came across the term *square degrees*. Immediately I began a fruitless search for its meaning. I decided to seek your aid. I should also like to find out how the number of square degrees in the celestial sphere is determined.—Andrew Skumanich, Wilkes-Barre, Pa.

Answer

Consider a very slender pyramid having a square section and let the *vertex* be at the observer's eye. The four plane *faces* of the pyramid intersect in its *edges* and these meet in the vertex. Let the angle between two adjacent edges be 1°, and suppose the edges

(and also the faces) to be produced to meet the celestial sphere. Each face will cut the sphere in an arc which is 1 degree in length, and the four arcs will bound a *square degree* of the sky. An angle of 1° at the eye is subtended by an arc 1 degree in length in the sky. We look on a square degree as so much area, but a square degree need not be in the shape of a square, just as a square foot of a flat surface may be circular or of any other shape.

We wish to find how many of these square degrees there are in the entire surface of the celestial sphere.

1. Geometrically.—Consider a cylinder circumscribing a sphere and touching it along a great circle, say, the equator. Now an old theorem dating back as far as Archimedes (d. 212 B.C.) states that the area of the surface of the cylinder is equal to that of the sphere. Next, develop the cylinder. It spreads out into a rectangle, the longer side being equal to the equator of the sphere, or 360 degrees of arc; and the shorter side being equal to the diameter, or $360/2\pi$ degrees of arc. The area is the product of 360 and $360/2\pi$, which equals 41,253 . . . square degrees.

2. Analytically.—By the integral calculus we find the area of the surface of a sphere is $4\pi r^2$. If r is measured in cm., then the area is in square cm. We wish to obtain the number of square degrees in the surface. This number does not depend on the length of r — it is the same for all spheres.

Now the circumference of a circle is equal to $2\pi r$; also it contains 360 degrees of arc. Equating these two quantities, we have $2\pi r = 360$, and $r = 360/2\pi$. Hence, surface of sphere $= 4\pi r^2 = 4\pi (360/2\pi)^2 = 41,253$ . . . . square degrees as before.

It may be remarked that this is one-fifth the number of seconds in a radian.

C. A. C.

A Chain of Meteors Seen in 1835

From "The Backwoods of Canada" by Catharine Parr Traill, in a letter dated, Douro (near Lakefield, Ontario) May 1, 1835, written to friends in England, occurs the following:

> I have seen the aurora borealis several times; also a splendid meteoric phenomenon that surpassed everything I had ever seen or heard of before.

I was very much amused by overhearing a young lad giving a gentleman a description of the appearance made by a cluster of shooting-stars as they followed each other in quick succession athwart the sky. "Sir," said the boy, "I never saw such a sight before, and I can only liken the chain of stars to a logging-chain." Certainly a most natural and unique simile, quite in character with the occupation of the lad, whose business was often with the oxen and their logging-chain, and after all not more rustic than the familiar names given to many our most superb constellations,—"Charles's Wain," "the Plough," "the Sickle," etc.

C. A. C.

L'ENFANT ET LES ETOILES (LEGENDE)

Par un beau soir d'été, non loin de la maison de ses parents, un enfant s'amusait à prendre des lucioles.

En passant près du puits il aperçut, tout au fond, des étoiles qui scintillaient comme des diamants.

Ce spectacle inusité l'attira longtemps; si longtemps que sa mère, un peu inquiète, dut l'appeler pour le repos de la nuit. Avec regrets il s'arracha à sa douce contemplation, et, dans son petit lit douillet, il en rêva longtemps.

Le lendemain, dès qu'il put sortir, il n'eut rien de plus pressé que de courir au puits. Mais hélas! lorsqu'il y plongea son regard, les étoiles avaient disparu.

Le coeur gros, l'enfant retourna vers sa mère qui, le voyant tout chagrin, lui demanda:

"Mais, qu'as-tu donc, mon chéri?"

— Maman! Maman! s'ecria-t-il tout effaré et les yeux mouillés de larmes, les étoiles se sont toutes noyées!

Montréal, Que. J.-EDGAR GUIMONT.

MEETINGS OF THE SOCIETY

AT MONTREAL

January 10, 1946.—In Moyse Hall, McGill University, S/L P. M. Millman, formerly of the David Dunlap Observatory, addressed the Montreal Centre on "R.C.A.F. Operation Eclipse"—the total solar eclipse of July 9th, 1945, as viewed from the air.

S/L Millman divided his address into three sections, dealing first with the reasons for observing the eclipse from the air, secondly, the problems one encounters in planning such an expedition, and thirdly, the results of the R.C.A.F expedition.

Of the three sources of solar radiation—the photosphere, the chromosphere and the corona—the first is the most intense and only evident source. For the scientist who wants to study the intensity of radiation, wave-lengths, and the distribution and polarization of light, an eclipse is important, for then the moon acts as a ready-made shutter, cutting off the light of the photosphere and making possible the study of the other two sources. With regard to the practical interest of the Armed Services in this study, S/L Millman spoke of the effects of the upper ionized atmosphere on radio and other apparatus.

Observing from the air has certain definite advantages. The aircraft can climb above the lower level of atmosphere, thus avoiding any low clouds that would interfere with ground observations. The darker sky is an advantage. There is less scattered light, and one is not bothered so much by haze on the horizon.

The task of photographing the eclipse from the air was assigned to No. 7 Photographic Wing, R.C.A.F., Rockcliffe, which has developed an unparallelled technique. A Spitfire, a Mitchell and two Ansons were employed. The speaker described the equipment used for both direct and spectroscopic photographs, gratings with 14,440 lines per inch being used for the latter, and focal lengths of the cameras ranging from 8 to 36 inches. The cameras, each with an automatic feature for exposures at 2 or 4 second intervals, were permanently mounted and so adjusted that they were directed at the sun when the pilot had the image centred on his sights.

In addition to the usual problems of aircraft maintenance, the effects of the high altitudes and low temperatures on the photographic equipment had to be considered. Navigation presented a special problem. The maximum duration of totality at the area selected was only 38 seconds, and it was essential that the aircraft, travelling at high speed, be at the right place at the exact time. For this purpose charts had been prepared showing the path of the shadow at altitudes of 17,000 to 35,000 feet. S/L Millman, who was navigator on the Mitchell, told of a few bad moments just before totality when he found that his watch differed from the other two on his plane by as much as five minutes although all three

time-pieces had been synchronized at the start. Which had been affected by the low temperatures? He decided to rely on his own watch which had served him well in the past and, fortunately for the success of the expedition, he made the right choice.

A number of slides were shown of direct photographs and spectrograms taken on the expedition as well as a film of the personnel, the take-off of the planes and other incidents. Regarding the scientific results, the speaker said that these could not be known until the spectra were examined photometrically. Visual examination, however, promised interesting results. Showing paired slides taken with twin spectrographs, he pointed out where in one slide the polarization was perpendicular to the dispersion while in the other it was parallel. A total of 35 direct and 29 spectrograms were taken. The series, it was felt, would be of value to Dr. Menzel for the calibration of the man-made eclipses at the Climax Observatory.

At the close of the address, D. P. Gillmor, past president of the Centre, moved a vote of thanks to the speaker, emphasizing the particular pleasure it afforded to hear a first-hand account of the expedition from one who had taken such an active part in the undertaking.

ISABEL K. WILLIAMSON, *Recording Secretary.*

AT MONTREAL

February 14, 1946.—Prof. G. H. T. Kimble, who occupies the recently created Chair of Geography at McGill University, addressed the Montreal Centre on "This Weather Business."

One of the earliest activities of man was to try to discover the rhythm of the seasons, and the meteorologist of to-day is still trying, concerning himself more especially with departures from the rhythm, Dr. Kimble said. He drew a laugh from his audience with the remark that he had already learned that the most regular feature of the Montreal climate was the January thaw. Weather moulds the life of man and plays an important part in war. Every kind of naval craft or naval operation is subject to its control. Aviation introduced a new complicated factor and radar "hasn't taken all the tears out of navigation".

It was in combined operations of the armed forces that weather played its greatest role. Dr. Kimble was one of the group that for two and a half years accumulated various kinds of climatic data, reviewing records covering a period of fifty years, to determine the best times and best points along the European coast for successful invasion of the continent. This study indicated that May was the earliest time of year for the kind of weather wanted and that it would not be safe after the end of August. A high tide was another essential which narrowed down the choice still further. As the speaker pointed out, although this extensive research did enable them to predict the average for any period, it did not eliminate the possibility of totally unexpected weather on any given date. If the venture had been postponed from June 6th to the next high tide, it would have met with almost certain failure, for on June 18th there arose a gale the

like of which had not been seen in the fifty year period under survey. The full significance of this will be realized when one considers that the rate of unloading drops fifty per cent when waves rise from three to four feet.

The war gave an impetus to long range forecasting. The Germans, in particular, were good at seasonal forecasting, predicting in broad terms for three months ahead and being right eight times out of ten. In the early years of the war their long range technique was undoubtedly better than that of the Allied Forces. The war taught the meteorologist much that will be of use in times of peace. Dr. Kimble spoke of the value of weather intelligence in fruit growing, civil aviation, etc. He paid a fine tribute to the Canadian meteorological service, which, he said, has a higher standard than any in the world.

Of particular interest to his audience were Dr. Kimble's comments on the Montreal weather as revealed by his study of records at McGill University. For instance, in Montreal we are more likely to have warm spells from December 7th to 11th than from December 15th to 20th. It is more likely to be warm on Christmas Day than on New Year's Day. The chances are three to one that the January thaw will occur around January 3rd to 8th rather than at end of January. While these striking periodicities are more reliable than the "ground-hog nonsense", the one thing that stands out clearly is that there is nothing certain.

In closing Dr. Kimble recommended that any of his listeners who wished an introduction to meteorology read, not a text book, but a novel—"The Storm" by George Stewart, for the author had spent some time at a meteorological station to collect his material which he presented in an authentic and very palatable form.

John W. Duffie, Secretary of the Montreal Centre, extended the thanks of the meeting to Prof. Kimble for his most interesting address.

ISABEL K. WILLIAMSON, *Recording Secretary.*

AT WINDSOR

March 12, 1946.—The Windsor Centre met at 8.15 p.m. in the Art Gallery of Willistead Library. The President, C. B. Hallam, welcomed a large audience. The members unanimously approved a resolution directing the Council to contact the seven local M.P.'s and M.P.P.'s regarding increased grants requested by the General Council from the Dominion and Provincial Governments. The secretary, R. G. Warwick, spoke briefly on the Astronomical Events of the Month. All present were invited to enjoy telescopic observations following the meeting.

Councillor F. W. C. Jones introduced the speaker of the evening, Prof. Orren C. Mohler, Ph.D. Dr. Mohler studied astronomy at the University of Michigan and at other observatories. He is presently engaged in solar research at the McMath-Hulbert Observatory at Lake Angelus, Michigan.

Dr. Mohler stated that the study of the sun is of vast importance. Because of the earth's position relative to the sun, we must of necessity investigate its

nature. In the number of unsolved problems, solar research commands first place in popular attention. Aided by motion pictures and lantern slides, Dr. Mohler discussed sunspots and prominences and their effects. Many members and visitors asked pertinent questions in a lively discussion period. In reply to a query about the effect of sunspots on the earth's weather, the speaker stated that he was not convinced that there was a direct relation between the two, due to other factors involved.

The remarkable motion pictures of the prominences made with the spectroheliokinematograph under Dr. Mohler's direction, were particularly effective. Gigantic eruptions were shown occurring and some of the matter is believed to reach the earth.

At the end of the question period Mr. H. Cunningham proposed a hearty vote of thanks to the speaker. After adjournment Councillor Spracklin directed observations with the four-inch refractor.

R. G. WARWICK, *Secretary.*

AT WINDSOR

April 9, 1946.—The Windsor Centre met at 8.15 p.m. in the Art Gallery of Willistead Library, Mr. C. B. Hallam presiding. Librarian E. J. Edwards was on duty to look after the lending of the books and magazines of the Centre and the library. An audience of record size, over ninety, almost filled the room. Treasurer C. A. Bell proposed that Dr. O. C. Mohler of Birmingham and Mr. R. T. Graham of Wyandotte, Michigan, be elected members—carried unanimously. The president then introduced Mr. Hugh Murray who spoke on the current astronomical events. By means of charts and diagrams, Mr. Murray outlined the positions of the major planets and constellations.

Councillor Mrs. Margaret Back of Detroit gave an entertaining introduction of the chief speaker, Mr. William Schultz, Jr., president of the Detroit Astronomical Society. She told how well qualified he was to speak on his subject: "Electronics, a Rapidly Expanding Science." He is head of the Science Department at the Cranbrook Boys' School, and an electrical engineer operating his own amateur radio station W8LME.

The speaker first reviewed the electron theory and illustrated his points with a remarkable set of slides. He emphasized that electrons flow freely through good conductors and not readily through insulators. He illustrated various uses of the vacuum tube and displayed various radio, cathode ray, X-ray and television tubes.

In comparing the modern vacuum tube with Aladdin's lamp, Mr. Schultz emphasized that its uses are diverse and its applications in industry are multiple and complex. Two films were shown, the first illustrating the physical properties underlying the operation of the vacuum tube. The tubes were shown functioning in such electrical phenomena as rectifying, amplifying and the changing of electrical energy to light and vice versa. In the second film, Mr. Lowell Thomas, commentator, explained the operation of radio transmitters, telephone relays and

the complex machines used in the construction of vacuum tubes in the General Electric and Westinghouse factories and the Bell Telephone Laboratories.

After Mr. Schultz had answered questions from the audience, which included many enthusiastic secondary school students, Mr. Bawtenheimer expressed the thanks of the Society for the splendid talk. Mrs. Back, secretary of the Detroit Astronomical Society announced the coming meetings in Detroit, and the Convention of the Amateur Astronomers of America at Cranbrook July 5-7, 1946. Councillor G. Spracklin directed telescope observing of the moon and Jupiter after the meeting.

R. G. WARWICK, *Secretary.*

AT WINDSOR

May 7, 1946.—The Windsor Centre met at 8.15 p.m., the President in the chair. The Treasurer proposed that Mr. David Geauvreau, Windsor, and Mr. William Schultz, Jr., Bloomfield Hills, Michigan, be elected members; carried unanimously. The membership is now 47.

The regular feature "Astronomical Events of the Month" was taken by Vice-President D. C. Bawtenheimer. Aided by maps and diagrams projected on a large screen, he discussed the major planets and constellations and reviewed the May sky highlights.

The President introduced the chief speaker, Mr. F. W. C. Jones, B.Sc., research chemist at the Sharples Chemical Company, Trenton, Michigan. Mr. Jones entitled his lecture "Eclipse Instruments, their Design and Operation." In illustrating his remarks, he used a series of finely drawn sketches on the opaque projector, and a large quantity of valuable equipment.

Using apparatus which he designed and made in his work-shop, Mr. Jones demonstrated the coelostat which he used at the eclipse of July 1945. He gave a comprehensive outline of the instruments used in solar research and photography, illustrating the working principles of the spectroheliograph, coronagraph, heliostat, and the coronaviser. This newly-designed instrument has an ingenious trap into which the surplus sun's rays are deflected. The black velvet lining successfully absorbs all these rays.

Of value to the members was Mr. Jones' wealth of information about filters, films, cameras, motors and other equipment which he finds necessary in eclipse observations. His mirrors are finished to an optically perfect surface, and aluminized on the first surface.

Mr. Jones stated that astronomy first engaged his interest after he had seen some of Russell Porter's excellent drawings in the *Scientific American.* His greatest delight, confessed Mr. Jones, is grinding, polishing and figuring mirrors and lenses on his own motor-driven grinder. At the end of an informal question and discussion period, Councillor Robertson thanked the speaker. After the meeting members had an interesting time examining the mirrors, lenses and coelostat.

R. G. WARWICK, *Secretary.*

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The Royal Astronomical Society of Canada

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
1890-1946

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton, London and Windsor, Ontario; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as over 1,000 members of these Canadian Centres, there are over 400 members not attached to any Centre, mostly resident in other nations, while some 50 additional institutions or persons subscribe to our publications.

The Society publishes a monthly "Journal" containing about 500 pages and a yearly "Observer's Handbook" of 80 pages. Single copies of the "Journal" or "Handbook" are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 3 Willcocks St., Toronto.

The Society has for Sale:

Reprinted from the "Journal" of the Royal Astronomical Society, 1936-1944.

The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

General Instruction for Meteor Observing, (revised 1940) by Peter M. Millman, 24 pages; Price 15 cents postpaid.

A Yoke Mounting for the Six-inch Telescope, by H. Boyd Brydon, 8 pages; Price 10 cents postpaid.

Setting Up and Adjusting the Equatorial Reflecting Telescope, by H. Boyd Brydon, 25 pages; Price 25 cents postpaid.

Occultations: their Prediction, Observation and Reduction, by H. Boyd Brydon, 76 pages, 1944; Price 60 cents.

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